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THE ASSOCIATION was organized in Boston, Mass., on June 21, 1882, with the object of providing its members with means of social intercourse and for the exchange of knowledge pertaining to the construction and management of water works. From an original membership of only TWENTY-SEVEN, its growth has prospered until now it includes the names of over **700** men. Its membership is divided into two principal classes, viz.: MEMBERS and ASSOCIATES. Members are divided into two classes, viz.: RESIDENT and NON-RESIDENT, — the former comprising those residing within the limits of New England, while the latter class includes those residing elsewhere. The INITIATION fee for the former class is FIVE dollars; for the latter, THREE dollars. The annual dues for both classes of Active membership are THREE dollars. Associate membership is open to firms or agents of firms engaged in dealing in water works supplies. The initiation fee for Associate membership is TEN dollars, and the annual dues FIFTEEN dollars. This Association has six regular meetings each year, all of which, except the annual convention in September, are held at Boston.

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This Association, as a body, is not responsible for the statements or opinions of any of its members.

REASONABLE REQUIREMENTS IMPOSED UPON WATER WORKS SYSTEMS BY THE FIRE PROTECTION PROBLEM.

BY CLARENCE GOLDSMITH, ASSISTANT ENGINEER, PUBLIC WORKS DEPARTMENT, BOSTON, MASS.

[*Read September 19, 1912.*]

In any water-works system the requirements imposed by the fire protection problem have very much in common with those involved in furnishing an adequate and reliable domestic supply.

The success of any enterprise is dependent upon its financial resources and the organization of its working force. Under ordinary conditions a per capita expense of from thirty dollars to forty dollars is necessary to develop an adequate water-works system. Climatic and topographic conditions, however, are the controlling factors, and in localities where expensive water rights have to be acquired, or where a wide range in elevation exists, the expense may increase to about double the above-named figures.

One of the fundamental difficulties encountered in properly developing a water-works system is the securing of necessary funds to develop the works in advance of the increase in consumption. In some cases this difficulty is due to lack of confidence in the engineering ability of the department, and in others to political reasons. No money is ever saved by postponing a proper development, for in nearly every case the delay causes a large

loss by necessitating a temporary construction which is comparatively useless in the regular development of the works, besides subjecting the inhabitants to extreme inconvenience, and perhaps exposing the city to epidemic and conflagration.

Instances of dilatory tactics in financing necessary developments are, unfortunately, too numerous; in fact, a large proportion of our cities outgrow their supplies or equipment before the necessary additions are made. For example, the city of Lawrence, Mass., was warned early in 1900 that the consumption had reached the winter capacity of the filter beds, which at that time were not covered. Yet no money was placed at the disposal of the water board until 1906, when a new covered filter was contracted for, but not in time for construction work to be completed before the cold weather set in. The supply available from the old filter was so seriously depleted during the exceptionally cold weather of December of that year and the following month that early in February not more than one million gallons of water was available in the reservoir. -At this time relief was afforded by water supplied from the mains of adjoining towns. If a large fire had occurred during the period of low water in the reservoir, it would have been necessary to take suction from the river, which is highly polluted with sewage, in which case an epidemic of typhoid fever would have been inevitable.

As a second example, the city of Worcester, Mass., may be cited, for we are all familiar with the conditions existing in that city during the summer of 1911, as described in the paper read before this Association by Mr. Frank C. Kimball.*

In 1902, the necessity of starting the development of the Asnebumskit supply was apparent to those who were acquainted with the needs of the city, and though Mr. Batchelder, our President, worked very strenuously each year during the intervening period to secure the necessary funds to prosecute this work, no considerable money was provided until 1911, and the result is well known.

The city of Detroit is to-day confronted by a lack of capacity in its pumping station and distributing mains.

I want to call your attention to a fact interesting to you all,

* JOURNAL N. E. W. W. A., Vol. XXVI, p. 113.

which, without doubt, has a deeper influence on the results obtained by our municipal works than one would at first suppose, and that is the small salaries paid to water-works superintendents and engineers. What private corporation capitalized at from two to five million dollars would for an instant try to secure a man to direct every detail of the business for the paltry salary of from $1 800 to $3 000 a year? Yet this is what a superintendent is expected to do in a water-works system of the class above mentioned, for a wise board of commissioners will always be guided by the opinion of its superintendent in all matters pertaining to the operation and development of the works. It is to be hoped that in these days, when efficiency is the watchword, and the operation of all city departments is more carefully scrutinized than formerly by the citizens, the advisability of securing and keeping in office capable men, and adequately recompensing them, will be recognized.

Of all the various methods of organization in vogue in the different municipalities throughout the country, no single one can be selected as a panacea. The trend of the times is to centralize authority, which is accomplished by the commission form of government and modifications of it. This method, unfortunately, does not assure the securing of properly trained men for the positions, and although the recall may be applied, it is doubtful if a second selection would be an improvement on the first. The great trouble is that so many water-works positions have been and are now being filled by men with no previous experience or training along such lines, and who attain and retain their positions through political influence, that the public is apt to be misled into the belief that any one can run a water-works system. Such an assumption is untenable, and appears absurd upon even a casual study of the question.

This undesirable state of affairs is being met by the adoption of civil service rules in many cities, and if the examinations are properly and impartially conducted, good results are bound to be obtained. Many works are operated satisfactorily under the direction of a board of water commissioners, and this method has much to recommend it. When composed of three or more members, the term of one expiring each year, such a board assures a

continuity of purpose, and a new member who has been most antagonistic toward certain policies of the board may become an ardent supporter of these policies after he has had an opportunity to study the situation at short range. Nevertheless, the ever-present danger of incompetence confronts us in this case as well as in the former, and works which have flourished long under boards of water commissioners may become suddenly disorganized through the election or appointment of men subservient to political influences and more concerned about private well-being than public welfare. One must conclude from the various examples that constantly come to our attention that the responsibility reverts to the mass of citizens who control the situation by their votes, and that progress toward a more businesslike control of water-works plants must be brought about by a campaign of education. Civil service as applied to employees has many good points in its favor. It secures long terms of service for employees and relieves in a great measure those in authority from the importunities of those seeking positions for themselves or for others. The desirability of not changing employees is equally important from the standpoint of domestic supply and fire protection. Much of the work of operation is accomplished by laborers who through years of experience have acquired skill and knowledge in their work, which is almost indispensable in cases of emergency. Yet there are some cities in which the department undergoes a complete change of personnel at intervals of two years.

In order to enable the employees, when well organized, to render prompt and adequate service, complete records, properly filed, and suitable quarters are necessary. A detailed discussion of the subject of records is impossible in a paper of this character, but because of its great importance, those most essential are here briefly referred to:

A skeleton map of the distribution system on a scale of about 1 in. to 500 ft., showing mains, gates, and hydrants, is of great use for reference purposes, and of particular value in making studies for the extension or reinforcement of the distribution system.

Detailed locations in plat form on a scale of about 1 in. to 40 ft., showing mains, gates, and hydrants, are indispensable, and it is

convenient in many cases to show service connections on these sheets as well.

Records of service connections, gates, hydrants, and meter locations should be arranged in card index form.

The location of gates on the distribution system and those on services larger than two inches in diameter should be arranged in convenient form for ready reference, and copies of these records should be supplied to all employees authorized to operate gates.

Records of pumpage or delivery of flow lines, as made by one of the several accurate continuous-recording devices now on the market, should be kept, and the pumping station records should show the complete performance of the equipment.

Records of pressure maintained at several points of the system should be secured by the installation of recording pressure gages.

The above-mentioned records, together with such necessary and desirable amplifications as may be called for, should be kept up to date. The more important plans and records should be in duplicate, and one set should be stored in a substantial fireproof vault. The question of guarding records against destruction by fire cannot be too strongly emphasized, and it is to be regretted that it is a subject which is often completely or partially neglected. The ordinary fireproof vault is of questionable efficiency in a conflagration, and in many cities it is the custom to provide safe storage at the supply works, but removed from the danger of sweeping fires.

The engineering office, which generally occupies a building in common with the executive and clerical forces, should have ample area for carrying on the maximum amount of work which is liable to devolve upon this branch of the service during periods of active construction. The room or rooms should be properly ventilated and supplied with both natural and artificial light. Partitions should be so constructed that the occupants shall not be subject to the intrusion of the public, or other distraction. Well-arranged filing cases and vaults should be readily available for the storing of all plans and records. A library should be provided which should contain the latest editions of the most desirable handbooks and scientific works bearing on the various subjects which have

to be dealt with in the design, construction, and operation of a water-works system, and in addition a file of the best engineering magazines should be available, so that the working force may keep in touch with work of a nature similar to their own carried on in other cities.

The storage yard, usually containing a repair shop and stable, should be of ample area, and so located that shipments of material may be conveniently and economically handled both from the cars and in the area covered by the distribution system. The yard should be so laid out with paved drives that all the stock shall be readily accessible, and chain falls, with either derricks or cranes, should be provided for handling the heavier pieces. Fittings, valves, and hydrants may well be kept in covered sheds. If the yard is located in a closely built-up district, it is particularly desirable that the buildings be of fireproof construction; otherwise, they should be equipped with sprinklers, standpipes, and hose. The shop should contain tools of the kinds and sizes required to do all but the heavier repair work, and particular attention should be paid to the lay-out of the meter repairing and testing rooms. The offices of the several branches of the work should be connected by telephone, and constant watch should be maintained at the repair shop in all cities having a population of over fifty thousand. The requirements mentioned thus far are necessary for the construction and maintenance of a water-works plant furnishing a reliable domestic supply.

Fire alarms should be received over the gong or tapper circuit of the fire-alarm system in one or more offices of the department, and at least one employee familiar with the distribution system and prepared to operate gates should respond to all first alarms in mercantile and manufacturing districts, and second alarms elsewhere. Provision in duplicate should be made for notifying the pumping station of alarms.

The experience of many departments, as well as of public service corporations engaged in similar work, is that the motor-driven vehicle has become a necessary adjunct to the equipment of every water-works system. It enables a prompt response in case of accident, and increases the efficiency not only of the executive force, but also of the laborers in many branches of the work.

There is hardly a plant of any magnitude on which one or more automobiles cannot be profitably operated.

The source of supply must be carefully studied before its adequacy from the fire protection standpoint can be determined with certainty. The total quantity of water used for the extinguishment of fires is proportionately very small, being approximately one tenth of a gallon per capita per day, or in round numbers about one thousandth of the total consumption, but for short periods of time the rate is very high. From a perusal of the consumption records of any well-operated works, the maximum hourly, daily, and monthly rates can be readily determined, and from a study of the structural conditions in the city — areas, heights, protected openings, exposures, occupancies, construction of buildings, etc. — the probable maximum quantity which would be required to combat a fire of large proportions can be estimated within reasonable limits. The number of fire streams required simultaneously in cities of average character has been discussed by our leading hydraulic engineers, with practical unanimity of opinion. Their estimates are based on actual practice, and the values given by Mr. Kuichling are expressed by the formula $Y = 2.8\sqrt{x}$, where Y equals the number of 250 gal. streams and x equals the population in thousands. This formula does not make any allowance for broken services, and should be applied only after a study of the local conditions has been made, for in many cities the size of the mercantile or manufacturing districts is not in proportion to the population. A very full discussion of this subject was presented to the American Water-Works Association last year by Messrs. Metcalf, Kuichling, and Hawley.* Although the chance of a large fire occurring during the hours of maximum consumption is somewhat improbable, nevertheless it is wise to err on the safe side, and to use the maximum hourly consumption figure in the calculations, although in most cases the maximum daily rate may be used with comparative safety. This step is not so unreasonable as at first appears, for any city should have its supply developed somewhat in advance of present requirements, in order to care for future growth. In cities not exceeding one hundred thousand in population, where the lawn-

*Proc. Am. W. W. Assoc., 1911, p. 55.

sprinkling is restricted to certain periods of the day, it is feasible to enforce an ordinance prohibiting irrigation during the progress of a fire, thus materially reducing the maximum rate for which the city would otherwise have to provide. In some cities, dependent upon fire engines, the pressure is so reduced by large fire drafts that the domestic consumption rate will drop appreciably. Such distribution systems cannot, however, be considered adequate for the service required of them.

There are many cities located on large lakes and rivers where a practically unlimited supply is available, and one does not have to give the question a thought, but in others it is a most important question with the engineer. In these latter the problem is varied, but resolves itself into some method of storage so that the maximum rates can be delivered to the distribution system. If the supply is derived from driven wells, they should be so developed as to furnish the maximum daily rate, and the maximum hourly and fire-flow rates may economically be cared for by storage in a covered reservoir available for delivering into the distribution system. If the supply is derived from storage from a large catchment area, the capacity of this storage should be ample to meet the demands made upon it through a series of dry years. In dealing with such a supply, the average daily consumption, and not the varying hourly rates, must be considered in determining the minimum capacity of the storage reservoirs.

The source of supply having been determined, the method of delivery to the distribution system confronts us. In many cases where the supply is derived from rivers and lakes, and generally when delivered from storage reservoirs, these sources are at an elevation sufficient to deliver the supply by gravity. In a few cases the topography of the country is such that the sources of supply are in close proximity to the distribution system, but in by far the greater number they are at some distance. In the latter cases, distributing reservoirs within or near the area served by the distribution system become an economical necessity, for their existence permits the use of much smaller conduit lines. These lines should have a capacity at least equal to the maximum daily consumption, and one such line cannot be depended upon unless the storage in the distributing reservoir is ample to furnish

the supply during the longest period that will be required to make repairs. The conduits delivering the Catskill supply to the city of New York, the Owens River supply to Los Angeles, and the Wachusett supply to the Metropolitan District of Boston, are not in duplicate, but the permanency of their construction and the storage provided along their routes and at their termini assures the continuity of the supply. On systems where there is more than one supply line, these lines should not follow the same route, as the failure of one may cause the failure of another, or both may be put out of service at the same time from the same cause, as was recently the case in Seattle, Wash. Where pumps are required to deliver the supply to the distribution system, the pumping station should be of fireproof construction. No valid excuse can be offered for not constructing stations absolutely fireproof. The installation of sprinkler equipment, standpipes equipped with hose, and chemical extinguishers, in the many existing stations which are not fireproof, should be strongly advocated. In all cases, oil should be stored outside the building, and all internal hazards should be reduced to a minimum. When stations are exposed to external hazards, outside sprinklers, water curtains, and wire-glass windows should be provided. On buildings having incombustible roof coverings and cornices these give reasonable protection.

The selection of the equipment of the station requires careful study in order that units of proper capacity and number to insure economic and continuous service may be provided. Plants which are supplied by pumpage may be broadly divided into three classes, namely, those which distribute from a storage reservoir, from an equalizing reservoir, and direct from a station. Under the latter class those which are supplied with an equalizing standpipe should be included, for in only small towns can a standpipe furnish any reasonable proportion of the draft, and in the larger cities it is a useless adjunct, as the pressure can be as uniformly maintained by means of pressure governors.

The stations which deliver direct to the system will first be considered. Their pumping capacity should be sufficient to deliver the maximum domestic and fire draft combined, with any two units in reserve; and the boiler capacity should be sufficient to

enable the pumping of this maximum draft by the most uneconomical units in the station, with one boiler out of service for repairs or cleaning. This requirement of two reserve pumps over and above the maximum capacity has frequently been questioned, one of the foremost objections offered being the large amount invested for machinery which may never be called into use. The answer to this objection will be given along the line of cost. If the city were located in close proximity to a hill of sufficient elevation to furnish the desired pressure, the advisability of building a reservoir of sufficient capacity to assure the supply would not be questioned. Such a reservoir would cost, in round numbers, about $5 000 per million gallons, which corresponds closely with the cost of high-duty pumping machinery of equal capacity; and low-duty or centrifugal pumps can be purchased at a much lower figure. Viewed from the cost standpoint, therefore, no argument can be adduced against installing pumps to perform the same function as the reservoir.

Where an equalizing reservoir is in service, the pumping capacity need not be as great as in the preceding case, but there should be one unit in reserve over and above the maximum possible draft for ten hours, minus the reservoir capacity. When a station delivers to a storage reservoir, the pumping capacity should be equal to the average daily draft during the maximum month. Such capacities may perhaps appear high to many who have successfully maintained an ample supply from stations which are not equipped with the above-mentioned reserve units, but no station can be considered reliable unless it can maintain the supply at all times, and it is not infrequent in a station containing four or five units for two to be out of service at the same time, and, although one of the units may be undergoing only trivial repairs, such as replacing valves or packing glands, it would nevertheless be impossible to get it back in service on short notice.

The capacity for coal storage should be sufficient to hold fuel enough to run the plant through any period in which the delivery may be interrupted by strikes or unfavorable weather conditions, and coal to meet such emergencies should, of course, be kept always on hand.

If the water is delivered direct from the pumping station to the

distribution system or to an equalizing reservoir, there should be two or more discharge mains, and their capacity should be such that with any one main out of service, the other or others could deliver somewhat in excess of the maximum domestic consumption; and, of course, it would be much more desirable if, under such circumstances, the maximum domestic and fire draft combined could be provided for. When delivering into a storage reservoir, one main having a capacity equal to the maximum daily rate is ample, for repairs can be made before the water in the storage reservoir will be exhausted.

To-day filtration plants are in operation in many cities, and the capacity of these plants need not be as great as the maximum hourly rate of consumption if enough filtered water is held in storage at some point on the works to provide for the drafts. On many plants this supply is provided by large covered clear-water basins which supply the high-lift pumps. In some plants a bypass is installed so that unfiltered water can be delivered direct into the distribution system in case the fire draft exceeds the capacity of the filters and exhausts the supply in the clear-water basins. Where the original source is contaminated, however, this expedient should not be resorted to, but provision should rather be made for additional clear-water storage, as an epidemic is even more undesirable than a conflagration.

The supply mains connecting the storage or equalizing reservoir with the distribution system should be bypassed around the reservoir, and of such capacity that the maximum rate can be delivered with any one main out of service. In some cases, the installation of cross-connections and suitably located gates in the supply mains enables their size to be somewhat reduced. Blow-offs should be established at all low points, for it often requires more time to empty a main and dispose of the water than it does to accomplish the actual repair work.

In the construction of force and supply mains, the question of material is often difficult to settle. Cast iron, wrought iron, steel and wood are each used with good results. Up to thirty inches in diameter, cast iron generally proves the more economical, but in larger sizes steel lines prove cheaper even if they have to be replaced within twenty-five or thirty years. Besides, it is im-

practicable to use cast iron in mains of more than sixty inches in diameter. The carrying capacity of lines constructed of either material gradually decreases, but the cast-iron lines can be cleaned and their capacity restored at a nominal cost. On the other hand, cast iron is subject to rupture, which will put the line completely out of service, while in the case of steel any general weakening of the structure is portended by small leaks. Continuous wood stave pipe has proved very reliable; it is almost always cheaper, can be readily repaired, and maintains its carrying capacity throughout its life.

All force and supply mains should be equipped with air valves at their high points, and they should be frequently inspected, for a defective air valve will cause a steel or wood line to collapse in case of a break at one of the low points.

There is no better item to observe than the per capita consumption records if one cares to make a snap judgment in regard to the efficiency of the operation of a water-works system, for almost invariably the high consumption rate is a sign of inefficiency, and, conversely, the low consumption rate is indicative of efficiency. The per capita rate which is necessary to meet modern conditions in our cities ranges from about 50 to 150 gallons per day, but these rates are exceeded in most of them. This unnecessary consumption has a very important bearing upon the question of cost, for it has to be met by the development of larger supplies, the construction of additional filtration works (if there are any), and the installation of additional pumping equipment and of force, supply, and distributing mains of increased carrying capacity, if the domestic and fire-flow requirements are to be fully met. Unfortunately, in such instances the fire-flow is generally only partially provided for during periods of maximum domestic consumption.

The installation of meters is the surest and practically the only way to effect a permanent reduction of the per capita rate. Many and fallacious as are the arguments advanced by the opponents of the general installation of meters, the results where they have been installed are incontrovertible. Water-works engineers are not as yet agreed that the metering of all services is an economic necessity, but the results attained in cities that have metered

practically every service show that as much benefit may be derived from metering the last ten per cent. of services as was obtained from any prior installation of an equal number of the same size. The water used in public buildings and for other municipal purposes is generally far in excess of that actually needed. In cities which have paid particular attention to this class of consumption, the conclusion reached is that all water used by the several city departments, except for the extinguishment of fires, should be metered and paid for by the users. Such a course not only effects an important reduction in consumption, but gives the water department credit for the service rendered.

One of the points upon which insurance and water engineers differ is in regard to the metering of fire services. The water-works engineer, who generally takes the affirmative side of the question, is in much closer touch with the situation, and when such results as the following are obtained, there seems to be no doubt in regard to the justification of his stand.

Worcester, Mass., metered all fire services in 1905, and the following year the revenue increased $15 000, and the consumption decreased over 300 000 000 gal.

Lockwood, N. Y., metered all fire services, and the following year the revenue increased 25 per cent. and the pumpage decreased 20 per cent.

The pressures which are maintained on works which are supplied by gravity from distributing or equalizing reservoirs are governed by the elevation of the reservoirs. In many cases suitable sites are not available at desired elevations, but when they are, it is highly desirable to so locate the reservoir that a pressure of 100 lb. will be maintained over the greater portion of the distribution system, and particularly in the closely built-up sections. In a recent paper,* Mr. E. V. French dwelt upon the advisability of such a pressure, and showed that it was sufficient to furnish direct hydrant hose streams to all fires except those in the larger and higher buildings, for which more powerful streams would have to be furnished by fire engines. As the number of fire engines can be greatly reduced if many streams can be taken direct from the hydrants, a very considerable saving can be thus effected,

* JOURNAL N. E. W. W. A., Vol. XXV, p. 247.

for it costs between three and four thousand dollars a year more to maintain an engine company (horse-drawn) than to maintain a hose company. In planning for extensive improvements in any city, therefore, it is desirable to provide, if possible, for the raising of the pressure to about 100 lb., for in addition to cutting down the expense of the fire department, other economies can in this way be also effected. Take, for example, the large cities of New York, Chicago, Philadelphia, and Buffalo: in these it is necessary to pump all the water used in buildings of moderate height and in small plants, and this could be done more economically in one central station. Of course it would still be necessary to pump the supply to buildings over 200 ft. in height, but these are comparatively few.

Next in importance to the saving which could be accomplished is the increased reliability of sprinkler equipments when supplied from a central station. The number of such equipments in service is increasing rapidly, and they constitute practically the only safeguard to buildings of non-fireproof construction and fireproof buildings containing combustible material. In many systems supplied by direct pumpage provision is made to raise the pressure upon receipt of fire alarms and maintain this pressure until the "all-out" is sounded. This practice is good, and may well be adopted in all such systems. The permanent raising of pressure on a system does not necessarily increase the consumption, for thorough inspection and the prompt following up of defects will enable an unincreased consumption rate to be maintained. This has been proven in several cities during the past few years, and though heavier materials, requiring more careful workmanship, are used in the original installation, the subsequent cost of maintenence of a distribution system under 100 lb. pressure is no greater than under 50 lb. pressure.

Few engineers have the opportunity to design a new distribution system for a city of any considerable size. New Orleans is the only large city which has installed a new piping system in the last score of years. The problem of to-day is the reinforcement and rehabilitation of outgrown distribution systems, or of systems which have deteriorated in carrying capacity or were faulty in their original design. To accomplish this task, a careful study

of the existing system should be made, present requirements determined, and proper allowance made for future growth. This done, a plan for all future work should be adopted and followed. This plan should include main arteries of ample carrying capacity girdling the city as its growth demands, secondary feeders of suitable size about 3 000 ft. apart in either direction, and dead-end lines extended to outlying sections without reduction in size, — the system to be so designed as to furnish fire protection as follows:

(*a*) In outlying residential districts not likely to become closely built up, a minimum of 1 500 gal. per minute.

(*b*) In closely built-up residential and minor mercantile sections, 2 000 to 5 000 gal. per minute.

(*c*) In manufacturing, warehouse, and congested value districts, from 5 000 to 20 000 gal. per minute, depending on the structural conditions.

The above supply should be in excess of the maximum daily domestic consumption, and should be available in manufacturing districts to any large group of buildings of special hazard, and in mercantile and residential districts about any block. In order that these quantities shall be available, the following minimum sizes of mains should be used for hydrant supply:

For residential districts, 6-in. and 8-in. mains, the former to be used only where they complete a good gridiron, and the latter in locations where dead-ends and a poor gridiron are likely to exist for some time, and in all blocks 600 ft. or more in length.

For mercantile and manufacturing districts, 8-in. and 12-in. mains, the former to be used only in sections where they complete a good gridiron, and the latter for long lines not cross-connected.

Four-inch mains cannot furnish sufficient hydrant supply, and should be replaced as fast as circumstances will permit, the replacement to commence in the more thickly built-up sections. In order that not more than one hydrant will be on a 6-in. nor more than two hydrants on an 8-in. main between intersecting lines, dead-ends should be eliminated wherever practicable, large mains cross-connected to distributors at all intersections, and long unsupported lines of pipe cross-connected.

The city of Reading, Pa., affords a good example of the results which may be accomplished by the adoption of a well-designed plan to be followed out in future construction. Some seventeen years ago such a plan, prepared by the superintendent, Mr. E. L. Nuebling, was approved by the city, and has been followed since that time. At present there are ample quantities of water available for both domestic and fire protection purposes throughout the entire system, and future additions to meet increased growth in population can be readily and economically made.

Unfortunately, the topography of some cities precludes the making of plans for future growth, for it is impossible to foresee in what direction that growth will extend. For a number of years the probable growth of Los Angeles appeared to be in an easterly direction, and it is only in the past two or three years that a definite trend showed it to be in a westerly and southerly direction.

Tar-coated cast-iron pipe is unquestionably the best material to install in a distribution system. In some parts of the country kalameined pipe is extensively used, because of the saving in freight rates which can be effected on account of its lighter weight, and this pipe gives very good results. Machine-banded wooden pipe does not give satisfaction in a distribution system on account of the excessive leakage which generally occurs. Cast-iron pipe should be inspected at the foundry and again before it is lowered into the ditch. Special care should be taken to prevent any foreign matter from getting into the line during laying, and the line should be thoroughly blown out before it is put into service. If practicable, a test pressure of one and a half times the working pressure should be applied to the line before backfilling.

Pipe less than 6 in. in diameter should never be installed to furnish hydrant supply. In cities where the distribution system is weak, it is desirable not to install any pipe less than 8 in. in diameter, for the new lines of these larger sizes will reinforce the old lines. The weight of pipe purchased should be sufficient to enable at least 300 ft. head to be maintained at the point of lowest elevation in the city. If the heavier classes of pipe are installed, it enables the pressure on the system to be raised to the desired point without the additional expense which would otherwise be required for relaying. The coefficient of carrying capacity of the

older lines should be determined by experiment, and in many cases, where the supply is deficient, the results obtained will show that it is more desirable to clean the line than to lay a new line. Sufficient cover should be provided to insure the pipe from freezing, even in the coldest winter. Exposed pipes at bridge crossings should be well supported and protected from injury, and extreme care should be paid to the design of the line near the approaches.

Electrolysis is a subject which must not be neglected, for it is most insidious in its action. Frequent surveys should be made, and remedial measures approved by the best water-works practice, rather than those generally advocated by street railroad engineers, should be adopted. Grounds from electric circuits should be made on the street side of the meters, main cocks, etc., in accordance with the National Electrical Code, and no power circuit which depends upon a grounded return should be connected to the system in any manner.

In order to operate a distribution system with the desired facility, the mains should be equipped with gate valves so located that no single case of accident, breakage, or repairs to the pipe system in important mercantile and manufacturing districts will necessitate the shutting from service a length of main greater than the side of a single block, or a maximum of 500 ft., or in other districts a length greater than two sides of a single block, or a maximum of 800 ft. If possible, the location of gates should be uniform; that is, they should be set on the property or curb lines at street intersections, so as to be more readily located. On paved streets it is advisable to provide a box or vault of sufficient size to permit of packing the gland without excavation. When the approximate location of a box is known, and it is covered by dirt on an unpaved street, or by ice, a pocket compass will prove an invaluable aid in determining its exact location, for by passing the compass over the supposed location, about an inch above the ground, the needle will deflect toward the iron cover, and by a little careful work can be made to indicate the exact center of the cover. The compass will determine the location of a box that is covered as deep as one foot. This method is also of use in finding cast-iron service boxes which have been covered by granolithic sidewalks.

The gate valves on a system should be inspected at least once a year, at which time they should be operated, and packed if necessary. The boxes should be kept clean, and if water is liable to collect and freeze in them, they should be provided with a drain to the sewer or be pumped out. All operating nuts should be of the same size, and all gates should operate in a uniform direction. On a system of any considerable size, gates should only be operated by employees specially assigned to the work, and a record should be kept by them of each operation. Careless inspection and operation is sure to cut down the carrying capacity of the system by allowing some gates to remain closed, and frequently causes serious delays in cases of accident. Occasionally division gates between different services are left open, and the apparent increase in consumption in the higher service is puzzling to the superintendent until the cause is discovered. In one city where a record of gate operation was not kept and inspections were infrequent, an examination of 7 000 valves showed:

49 closed and 300 partially closed valves on lines from 4 to 20 in. in diameter.
12 inoperative valves.
100 valves either not on the plans or not in the ground.
2 gate vaults completely filled with crushed stone.
1 division gate open.
1 952 boxes requiring cleaning.

In a smaller city an inspection of 40 valves showed:

1 valve closed.
1 valve with a broken spindle.
1 valve so deep that it could not be reached with the wrench.
2 valves operated in a direction opposite from the others, and no note made of the fact on the plans.
2 valves inaccurately located on the map.
3 valve boxes filled with bricks and earth.
1 operating nut too large for the wrench.

The hydrant is the last link in the chain from the source of supply to the point of delivery to the fire hose lines. Hydrants should have 6-in. barrels with 6-in. gated connections to the main and a foot valve having a free waterway of at least 20 sq. in., so that the loss when 1 000 gal. are being withdrawn shall not be

excessive. In cases where provision is made for more than one engine to take suction from a single hydrant, the above dimensions should be increased, and no loss greater than 4 lb. should be permitted when hydrant hose streams are utilized. The operating nuts of all hydrants in a system should be of uniform size and turn in the same direction. Where hydrants are supplied from different services it is advisable to paint those on separate services a distinctive color. Care should be taken to have the threads on the outlet nipples of the same size as that adopted by the fire department for hose couplings, and it is especially desirable to adopt the National Standard hose thread, so that apparatus summoned from neighboring cities can make connections.

Hydrants should be frequently inspected to assure their operation. They should be packed and lubricated, and the outlet caps greased, at least once a year, and they should then also be operated and blown out. Before cold weather sets in they should be carefully inspected for drainage, and if any are set below the ground-water level the drips on such should be plugged and the water in the barrel pumped out. During periods of cold weather those in high-value districts should be inspected once a day, and those in other sections twice a week. Special connections should be provided for filling flush wagons and sprinkling carts, and the use of fire hydrants should be confined solely to the fire department.

The question of the distribution of hydrants in a city is a very important one from the fire department standpoint, on account of the great friction loss in long lines of hose. The distribution should be such that ample quantities of water can be delivered to a large fire from hydrants at an average distance therefrom of not more than 350 ft. The customary method of figuring hydrant spacing on a linear basis does not convey any definite information, for, without a knowledge of the size of the blocks, linear spacing would be apt to convey an erroneous impression. For example, the locating of hydrants at linear distances of 200 ft. in one city where the blocks are 200 ft. square would, in the matter of distribution, be equivalent to the locating of hydrants at linear distances of 100 ft. in another city where the blocks are 800 ft. square — in either case the area served by a single hydrant being 40 000 sq. ft. Under the differing block conditions referred to,

Portland, Ore., illustrative of the former, would require one hydrant at each street intersection, or one hydrant to a block; while Salt Lake City, illustrative of the latter, would require 16 hydrants to each block between the center lines of the four bounding streets. It is clear, therefore, that the area in square feet served by each hydrant is the proper unit to adopt in order to be able to determine the adequacy of hydrant distribution and to make comparisons. Where it is necessary to concentrate 10 000 or more gallons of water per minute upon any building or block, there should be one hydrant for each 40 000 sq. ft. In minor mercantile and small manufacturing districts and in densely built-up frame areas, there should be one hydrant for every 60 000 sq. ft., and as the buildings become less congested the distribution may become wider, up to 120 000 sq. ft. in outlying residential sections.

From the operating standpoint the inside independently-gated hose outlet cannot be considered as giving the best results. The leverage furnished by the wrench ordinarily used by the fireman is far in excess of that required to operate a valve of equal size in any other service, and so great that the stem can be broken or other parts crushed without any undue exertion on the part of the operator. The end to be attained may best be accomplished by attaching outside hose gates before the hydrant is open, and such a procedure will not introduce an objectionable delay. Such gates carried on hose wagons are more reliable, as they can be easily inspected and kept in working order.

The matter of original expense is also a very important item. Assume a city with 2 000 hydrants and 16 hose or engine companies. To equip the $2\frac{1}{2}$-in. outlets on all the hydrants would cost over $20 000, while to supply the 16 companies, each with four hose outlet valves, would cost about $650, and the cost of maintenance would be in about the same proportion. It is not so practicable to deal with the $4\frac{1}{2}$-in. steamer outlets in the same way, because the portable valve is much heavier, so where it is desirable to connect a steamer to a hydrant which may already be delivering to a hose line, or where there are two steamer connections on a hydrant, it proves more convenient to equip these outlets with inside gates.

The purchaser of a hydrant should insist upon having the waterways carefully designed, the castings smooth, and the workmanship good. The neglect of these points often admits of the installation of a type of hydrant which is well-nigh valueless. There are hydrants in service in some cities to-day which show a loss of 35 lb. between the street main and the hose outlet when 600 gal. of water are being drawn, whereas there are many hydrants of reliable make and at reasonable cost which can deliver the same quantity of water with a loss of less than 4 lb.

The requirements necessitated by the fire protection problem are, of course, a large factor in the cost of a water-works system, increasing that cost from 50 to 100 per cent. over what it would be were the question one solely of furnishing water for domestic and business purposes. But these requirements have to be met, and while in no one city are they all fully provided for, a large number of our municipalities are earnestly endeavoring to attain the best possible results in this connection, and it is to be hoped that their example will be speedily followed by those that now lag behind in the matter of water-works administration.

It is evident from the foregoing that the fire protection problem is one of the first importance for the water-works engineer, for it is primarily with him and the fire department that its solution lies. It is perhaps not to be expected that any water-works system will fully meet its requirements in all their complexity of detail, but while the ideal is never attainable, it is always more and more nearly approachable. That it may be the more nearly approximated to in the design, construction, and maintenance of a water-works system, our municipalities should make it an indispensable part of their policy to secure for this work the best engineering talent available, and then leave it unhampered by political or other considerations to pursue its course toward the realization of what men are striving for and municipalities hoping for, — the watchword of the century, — a maximum of efficiency at a minimum of cost.

DISCUSSION.

MR. FRANK L. FULLER.* Mr. President, I think the author has set a high standard for water-works construction, and while there are details as to which engineers and water-works men would differ, still it seems to me that on the whole he has given us an admirable lay-out. He deals, perhaps, more particularly with systems for cities and large towns, while works that are being built at the present time are generally for smaller towns, and the requirements for them, therefore, would probably not be equal to those represented in this paper.

MR. W. C. HAWLEY.† Mr. President, this excellent paper has covered the ground thoroughly, and every practical water-works man will agree to a very large extent with the opinions which have been expressed. It brings us to the question of the cost of all of these things which enter into the construction of a well-designed and well-built water-works system and *who is going to pay for them*, and that, I believe, is one of the matters that we have got to study into, and about which we must educate the public. Those of us who are connected with privately owned plants are confronted with this problem constantly. A neighboring municipal plant is selling water at a low rate per 1 000 gal. and is not charging for fire protection. Nothing is said as to how much is being raised in the municipality by direct taxation on account of the municipal water department or the quality of service or that probably no depreciation is being earned, and the result is that the comparison of rates between the municipally owned plant and the privately owned plant is most unfair, and yet a large part of the community supplied by the latter is firm in its belief that the grasping private monopoly is robbing the people because its rates are higher than those charged in the municipality.

The investment in water-works plants for furnishing fire protection may vary from 80 per cent. of the total cost of the plant in the case of a small water works down to a very small percentage of the total cost in the case of a large one. It is not fair that the expense of furnishing fire protection should be met by the domestic

* Civil Engineer, Boston, Mass.

† Chief Engineer, Pennsylvania Water Co., Wilkinsburg, Pa.

or the industrial rates, but it should be met in the case of the municipal plant by direct taxation, and the people should know what they are paying for and what it costs. In the case of privately owned plants a charge to the municipality must be made for fire protection, to be raised by taxation, or else the cost of furnishing fire protection must be added to domestic and industrial rates. Few, if any, water companies are charging what it is actually costing them to furnish fire protection, to say nothing of a reasonable profit upon the business. The computation of the cost of furnishing fire protection is a matter requiring skill and judgment, and cannot, of course, be made with great accuracy. In its calculation, however, so far as I know, every question involved has been solved by giving the benefit of the doubt to the fire protection; and even when a minimum cost has been computed, few, if any, water companies have named rates which would return the cost of the service. In some cases it has been customary to purposely add a part of this cost to domestic rates, and this has been justified on the ground that fire protection is received on both buildings and contents and that in many cases the contents do not belong to the owner of the building but to the occupant, who is either directly or indirectly the one who pays the domestic rates, and in this way he bears a share, at least, of the cost of furnishing fire protection.

Rate-making in the past has been to a large extent a matter of guesswork, but with the introduction of public utility commissions throughout the country, rate-making will be put on a more scientific basis. Sooner or later, we are all going to be confronted with this problem, and we shall have taken a long step in advance when the public comes to know something about the investment necessary to furnish fire protection and what it costs, and meets it by direct taxation instead of by some species of indirect taxation as at the present time.

SOME DIFFICULTIES ENCOUNTERED IN TUNNEL AND SUBWAY CONSTRUCTION IN BOSTON.

BY FREDERIC I. WINSLOW, ENGINEER OF EXTENSION, WATER SERVICE, PUBLIC WORKS DEPARTMENT, BOSTON, MASS.

[*Read November 13, 1912.*]

This paper is divided into several parts, the first relating to the pipe changes in connection with the various subways built to date in this city; the other parts describe two compressed air tunnels; the building of the Deer Island Reservoir, and some other work on which the author has been employed.

TREMONT STREET SUBWAY.

When the first subway was built in 1895 — about 1 200 ft. of Tremont Street was taken for its location. The City had had since 1847 along this line two 30-in. pipes laid about 5 ft. apart on centers, and the subway roof came either just up to or just above the level of both these pipes. It was proposed at that time to relay them entirely away from and around the subway so as to avoid all difficulty of caring for them during construction, and later events have rather proved the wisdom of such a course. It was, however, not adopted, and it therefore devolved on the water department to maintain these pipes by shifting, raising, or lowering them as was necessary for the construction of the subway, all with the coöperation and assistance of those in charge of building it.

The subway was constructed by the " cut-and-cover " system; that is, alternate sections of about 20 ft. were opened at the same time and work carried on under cover of planks at the street surface. Work was never stopped, either at night, on Sunday, or on a holiday. The city maintained but one inspector on the work all the time, with three shifts. The conditions found after several breaks had occurred demonstrate and emphasize the importance

of the thorough inspection of work involving the foundations for heavy pipes.

There were at the same time perhaps twenty of these 20-ft. sections being worked on, in various stages of construction. The instruction given to every one concerned was to allow no rigid material to be set nearer to the bottom of the pipe than 4 in., that is, the pipes, as the old foundations were undermined, were set on 4 in. of blocking, and the subway roof was carved out under the bells where necessary to allow 4 in. of earth between the

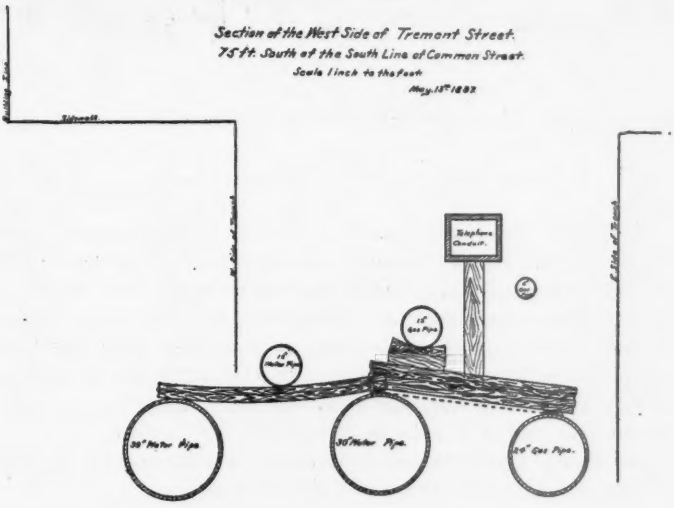

Section at the West Side of Tremont Street.
75 ft. South of the South Line of Common Street.
Scale 1 inch to the Foot.
May 15th 1897.
Sidewalk
W. Side of Tunnel
E. Side of Tunnel
Telephone Conduit.
12" Gas Pipe
12" Water Pipe
30" Water Pipe
30" Water Pipe
20" Gas Pipe.

FIG. 8.

pipe and any rigid material underneath. These orders, if faithfully carried out, would have prevented large financial loss and annoyance from breakage, although to have carried them out would have required at least four times as many inspectors as were employed, and it was not at that time realized that such plain directions as were given would be so disregarded. There have been, so far, eight breaks of either one or the other of these pipes over the subway, costing for repairs about $9 000, and over

$50 000 more for damages. In every case where a pipe broke, it was at a point where it could settle, in close proximity to a rigid bearing where it was so firmly held that it could not yield, and under the enormous leverage the pipe cracked invariably along the center line of the bottom. Figs. 8 and 9 show sections of the pipes as found after the breaks.

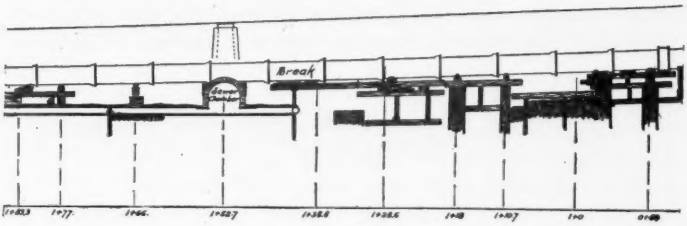


FIG. 9.
SHOWING SUPPORTS FOUND UNDER PIPES.

The two 30-in. mains before referred to had to cross the subway at a point on the Common, and, on account of the head room over the subway being so slight, these pipes had to pass under it. This was done by means of a sub-subway about 40 ft. below the surface of the Common, the pipes at this point being 30- and 40-in. respectively. The old pipes were maintained in service until the new ones were turned on, the work being done at night, on Sunday, and on a convenient holiday. The angle made by the pipes with the crossing was so acute as to make the length considerably longer than the width of the subway.

It is the policy of the water department to use as few single-casting quarter-bends as possible, especially in the larger sizes, so that two one-eighth bends had to be used wherever a 90-degree curve was necessary. As has been found many times, and probably referred to in past meetings of this Association, two eighth-bends rarely fit so as to make one quarter-bend, due probably to improper allowance made for shrinkage at the foundry. It was after considerable trouble, therefore, that these bends were finally fitted and anchored in place. The manner of anchoring is shown in Fig. 10.

Reinforcing rods were so set as to hold the masonry in place against a considerable head in case any leak should develop in the pipes, the water appearing first at a manhole on the surface of the Common. The shafts are filled around the pipes solidly with concrete, the curves in addition being anchored in place. This work was designed by the Transit Commission.

During the construction of the subway one of the 30-in. mains was moved laterally about 5 ft. and at the same time lowered 18 in.

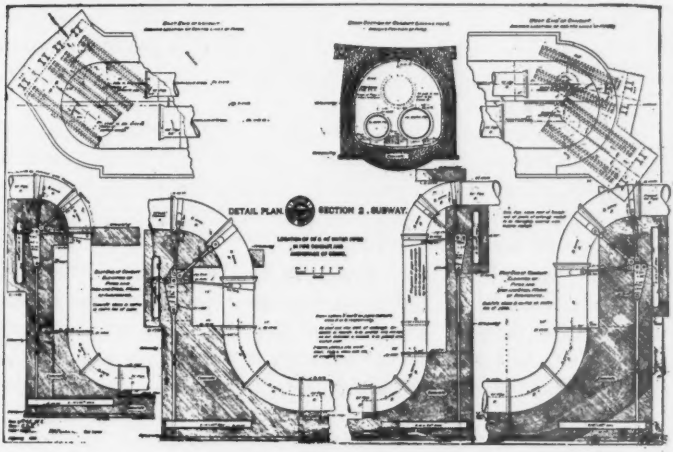


FIG. 10.
THE 30-INCH PIPE CROSSING UNDER THE SUBWAY, SHOWING THE METHOD OF ANCHORING.

This was accomplished at one operation. The pairs of timbers between which the lifting screws were operated were set on an incline on rollers, the lateral movement being made by barring, the pipe then dropping by its own weight as the screws were simultaneously loosened. Plate XII, Fig. 1, shows the method of shifting this pipe.

THIRTY-INCH STEEL PIPE.

When the second subway, or tunnel, so-called, was built under Washington Street, it was decided to avoid all possible future

trouble, at least over the subway, by laying about a mile of 36- and 24-in. pipe around and well away from the site of the work. This was done by the regular force of city laborers, chiefly on account of the supposed difficulty of doing this kind of work by contract in crowded city streets. This is the first case of a pipe of this size laid through the extremely congested streets of Boston. It was slow and expensive work, and many corporations felt that their vested or acquired rights in the streets were being ignored, and although every attempt was made to avoid the disturbance of other structures wherever possible, many of them were compelled to give way as the main was laid. Where the Washington Street tunnel was crossed, two right-angle turns were made, about 25 ft. apart.

As it was an exceptionally poor place to anchor curves, and as the tunnel was planned so near the street surface as to render it impossible to lay the proper size of pipe, it was decided to lay a short piece of 30-in. flanged-steel pipe, including the two bends. This insertion has so far given no trouble.

At the time the subway was built in the Common, the City desired to lay a 24-in. high-service main across the proposed subway at West Street. As was often the case, there was no room for that size of pipe over the subway, so three bays were left in special construction, and three 16-in. pipes were laid instead.

CASTLE SQUARE.

When the South Station was built, the old roadbed of the Boston & Albany Railroad was doubled in width as far out as Back Bay Station, involving the lengthening of all the bridges. At Castle Square the City had two 30-in. pipes crossing by an overhead bridge. The widening was so planned as to permit a street to be used directly over the new roadbed. This made the thickness of the street at this point too little to permit of a larger size pipe than 20 in., so four 20-in. pipes were laid in place of the two 30-in., wye branches being used at each end. Some fear was felt that a long line so little protected might freeze, and as at that time a patented covering, composed of felt, resin, and tallow, was coming into use, one inch of this was put around these pipes. Under these pipes, to protect them from the blast of the locomotives,

FIG. 1.
THE METHOD USED IN SHIFTING 30-IN. PIPE.

FIG. 2.
PIPING AT CASTLE SQUARE.

cement mortar was thrown, below this being a plastered wire netting. Over the bays was placed a steel plate, on which rested the roadbed composed of asphalt 1½ in. thick.

For some years observations of temperature were made at this point, but the water in the pipes never reached the freezing point. Plate XII, Fig. 2, shows the work at Castle Square about half completed.

COMPRESSED AIR TUNNELS.

The earlier pipe crossings of the harbor were made by siphons where the pipe was embedded in concrete enclosed in a heavy wooden box, and the entire siphon sunk in one piece. As changes occurred in depth or width of the channels, it appeared wiser to make these crossings safe and beyond the reach of any future disturbance. Accordingly three crossings were made in 1904 and 1905, of which two, the one at Dover Street and the one at Mystic Wharf, were in charge of the writer. As all were done under similar conditions, a description of one fits all.

The longest of the three tunnels was at Mystic Wharf, where the distance between the shafts was about 550 ft. The shafts were 60 ft. in depth. In every case a wrought-iron cylinder was sunk over the shaft location, and weighted so that it would sink well into the mud before the air was put on. The cylinder was then lined with the brick as designed, causing still further settlement. The small air lock was then put on and on the application of the air, the water lowered in the cylinder. The process of operation from this time was to excavate from 4 to 6 ft. beneath the lower flange and for 1 ft. out from the inner edge of the cylinder, and then to lay brick in its permanent position in the shaft, the cylinder being supported by its own friction. A circular row of pipes had been driven around the shaft to guide and hold it in position.

Speed is always slow on this part of the work, on account of the restricted space in which to lay brick. The shafts were 8 ft. internal diameter, the excavation was almost wholly in stiff blue clay, with some sand seams. The lines were maintained from a base line 4 ft. long, from holes bored in the bottom plate of the air-lock, piano wire being used with plumbs in water at the base of the shaft. This line was produced, and operations repeated again

and again, and from this short base line, no appreciable error was found when the second shaft was opened 550 ft. away. Plate XIII shows the general plan of one of the tunnels.

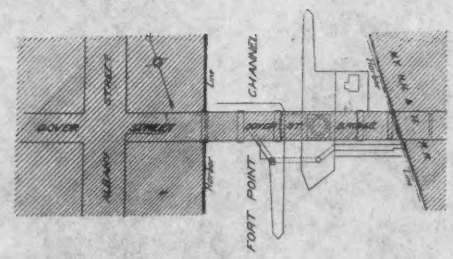
The mode of procedure in tunneling was as follows: A length of 10 ft. of the upper half of the tunnel was excavated, the material being carved out easily, and the roof was then held in place by curved flanged plates supported by posts, the plates being bolted and left in place, forming the backing for the brick. The lower half of the tunnel was then removed and the bricks laid in the entire section. The men worked in 11-hour shifts throughout the work, and a speed of 5 ft. of finished tunnel per day was made. Occasionally 10 to 12 ft. would be excavated in one day. The brick lining was 1 ft. in thickness. A specially fine sand was used for the purpose of reducing leakage into the tunnel. After some months, however, all the tunnels were found filled with water. The inside of the tunnel was plastered with neat cement, no waterproofing material being used. The distance between the top of the tunnel and the bottom of the channel was 17 ft. The air-pressure varied from 18 to 24 lb., but one compressor being in service, excepting for a short time toward the end of the work. One tunnel carries a 16- and a 24-in. pipe, the other a 30-in. pipe.

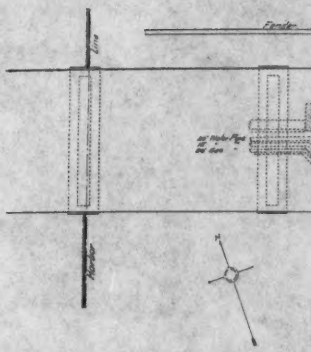
It is believed that the greater safety of the pipes, the ease of making repairs, and the fact of the pipes being beyond the reach of any probable change in the channel more than compensate for the increased cost of this method over the older method referred to previously. Plate XIV, Fig. 1, shows the method of construction in tunnel.

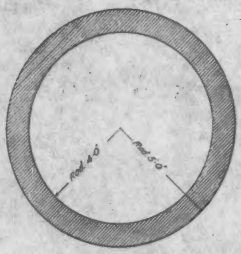
DEER ISLAND.

Deer Island is near the mainland on the north side of Boston, and is used by the City for its penal population. The original pipes across Shirley Gut were two 8-in., laid so near together that if one broke the other was also liable to go. These were laid in 1871.

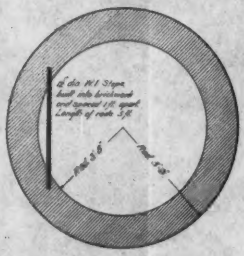
In 1896 an 8-in. pipe was laid across Shirley Gut, followed four years later by a 12-in., laid some distance away. The two types of flexible joint used in this vicinity are shown in Figs. 11 and 12. Fig. 11 design shows the style of joint in the old pipes; it resembles the old Ward flexible joint, in that the score is cut into the spigot,



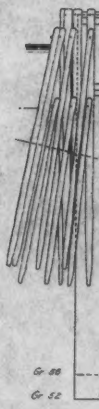




SECTION THROUGH TUNNEL ON LINE C-D
SCALE 1/4 IN. = 1 FT.



SECTION THROUGH SHAFT ON LINE E-F
SCALE 1/4 IN. = 1 FT.



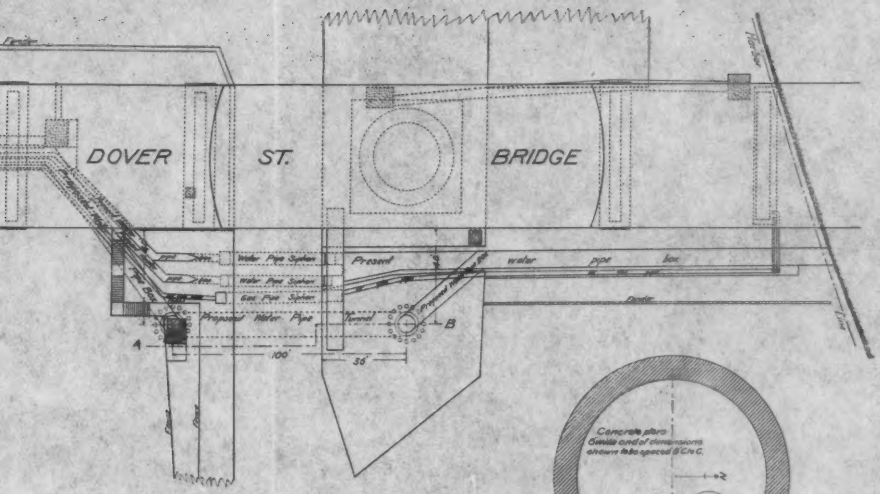
DOVER ST. BRIDGE-WATER PIPE TUNNEL
OCTOBER 1904
William Jackson
City Engineer

CITY of BOSTON - ENGINEERING DEPT.
PLAN AND DETAILS
OF
PROPOSED TUNNEL for WATER PIPE
ACROSS FORT POINT CHANNEL
AT
DOVER ST. BRIDGE

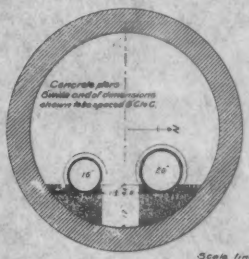
SCALES AS SHOWN

Note: Base used on this plan is 100 ft. below Boston City Base

No 2911.
Approved by Harbor and Land Comm
Boston Oct 26, 1904.
Thos. Worthington
Chas C. Peters
Chas E. Smith

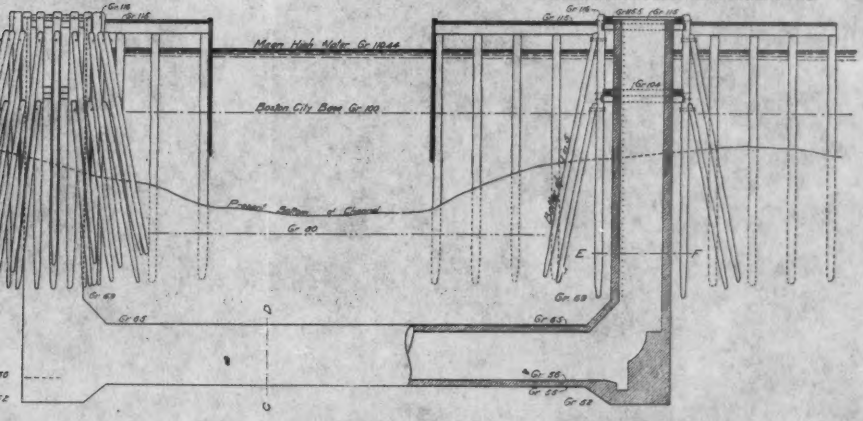


PLAN OF DOVER STREET BRIDGE
SHOWING LOCATION OF PROPOSED WATER PIPE TUNNEL
SCALE 1 in. = 20 FT.



Scale 1 inch = 2 FT

SECTION SHOWING LOCATION OF WATER PIPES.



LONGITUDINAL SECTION THROUGH LINE A-B
SCALE 1 in. = 1 FT.

so that whenever a change occurs in the relation of two adjacent pipes the lead emerges from within the bell. The objection to this form of joint is that when the two pipes reassume their original position, the lead is liable to be skived off. In Fig. 12 design, which has been in use in the vicinity of Boston since 1895, the lead is held within the bell and does not emerge when the pipe shifts

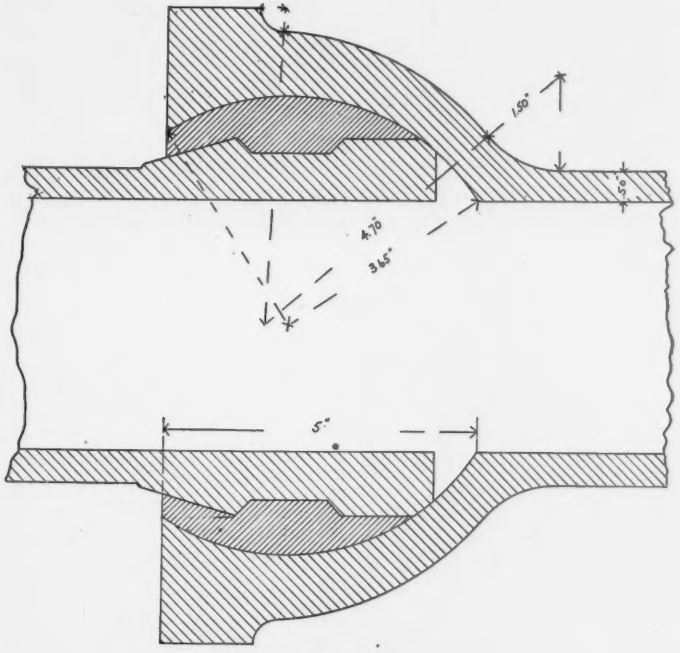


FIG. 11.

FLEXIBLE JOINT WITH LEAD ON SPIGOT.

position. In laying, the pipe was placed on rollers in a long runway on the bank, and as the distance across Shirley Gut was but about 500 ft. it was easily pulled across by a capstan arranged on the opposite shore.

After these pipes were laid it was decided as a further safeguard

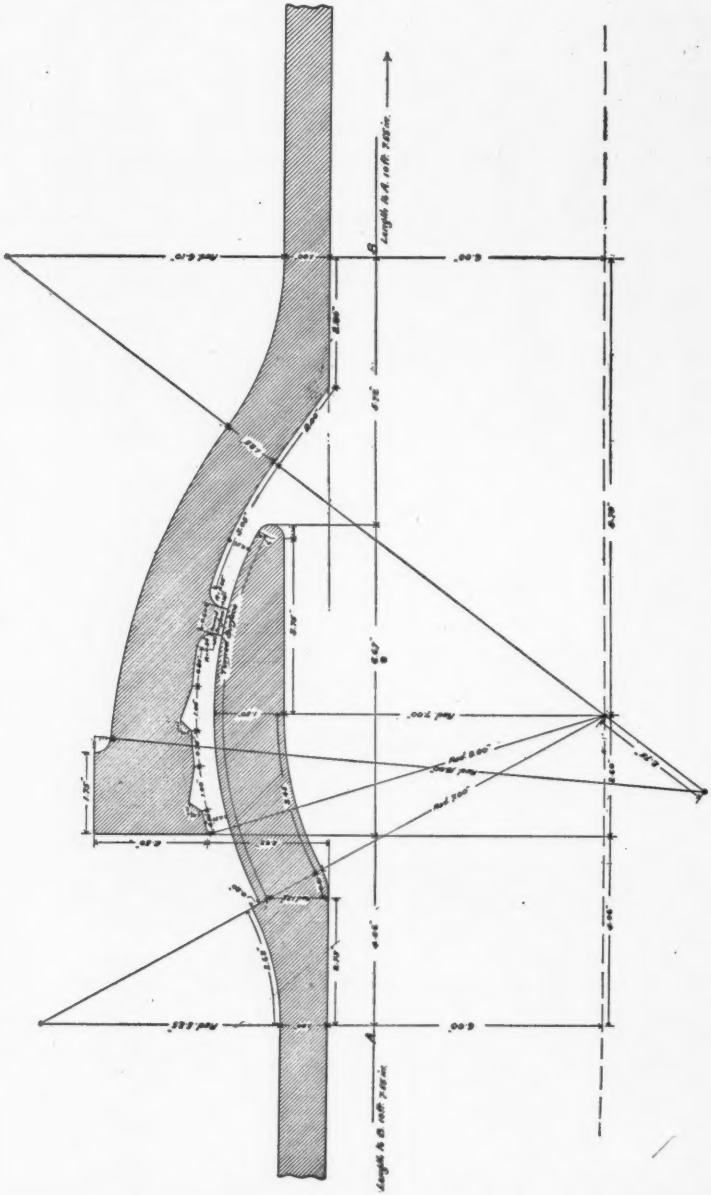


FIG. 12.
FLEXIBLE JOINT WITH LEAD IN BELL.

FIG. 1.
TUNNEL CONSTRUCTION.

FIG. 2.
METHOD OF LAYING PIPE TO SPECTACLE ISLAND.

to the 1 000 to 1 800 involuntary inhabitants of the island to build a reservoir large enough to hold some weeks' supply and at an elevation sufficient to feed the highest buildings. The size settled on was of two and one-half million gallons capacity, the dimensions being 138 ft. by 43 ft. on the bottom, 231 ft. by 136 ft. at the water line, and 282 ft. by187 ft. at the extreme outside path. The reservoir was so designed as to equalize the cut and fill, but was slightly sunk to avoid too high a bank, as the Government proposed to have a station near by on the island for heavy gun practice.

The material of this hill, like all the drumlins in the vicinity of Boston, is an almost impervious hardpan, and rain falling on it would remain until evaporated. The peculiar features about this reservoir were the long time required in building it, and the low cost of the the labor involved. It took six years in building, all labor except a few foremen being taken from the ranks of those who were serving their county by working with no compensation save bed and board, or, in other words, " doing time " at a city seaside resort. They therefore had no particular incentive to labor, or to turn out specially good work, although they did do so.

The hours of labor were not lengthy, three and one-half hours in the forenoon, and two and one-half or three in the afternoon. There was no opportunity on this work to actually compare the labor with high-priced or free labor on similar work. Some years ago, however, the writer did compare the two kinds of labor in laying a mile or two of pipe, and found that the efficiency of the unpaid labor was from one eighth to one tenth of the paid labor.

High-water mark of the reservoir was elevation 109 ft. above City Base, the top of the bank being at elevation 114 and the bottom of the reservoir at elevation 88. The inside slopes were 2 to 1, the outside slopes being $2\frac{1}{2}$ to 1. All work in excavation was carefully trimmed to 6 in. below grade, and filled to grade with concrete of 1 : 2 : 4 mixture, the finished surface being plastered so as to present a smooth appearance. A flight of steps was constructed in order that sediment may be carried out from the bottom. No drainage pipe was provided, in order to save expense; in fact, all expense for materials was cut as much as possible.

The site was first stripped of the thin layer of loam found on the

island and the banks were built up in layers of less than 6 in. in thickness, and very thoroughly rolled when wet with a grooved roller, all large stones being removed. Up to the present time the reservoir has been filled and emptied several times, and there has never appeared to be any leakage or head behind the concrete lining, and no leakage has shown through the bank.

The overflow consists of a 16-in. pipe laid on a large block of concrete going well down into the concrete beneath the stone chips. The one pipe serving as intake and outflow is a 12-in. This was laid from the bottom of the reservoir to the gate chamber in tunnel. This tunnel was braced, in order to avoid any possible suits for damages, although it would undoubtedly have stood alone. To prevent leakage through this tunnel, it was back-filled with lean concrete.

The flow into the reservoir had to be controlled to prevent overflowing, so that the method shown of three 2-in. inlet pipes controlled by 2-in. ball cocks with 12-in. floats was adopted.

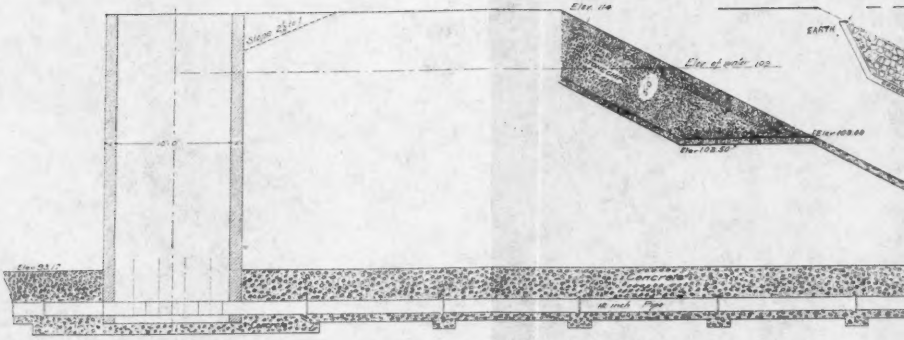
In the ordinary operation of the reservoir the check valve in the bottom of the chamber is shut by the pressure against it, water rises to the tank and flows down beyond the check valve into the reservoir. If the head in the pipes on the island drops, the reservoir acts automatically and the check valve opens. There are of course check valves on the island side of the two mains across the gut, so that if the pipes break, the reservoir would not be emptied.

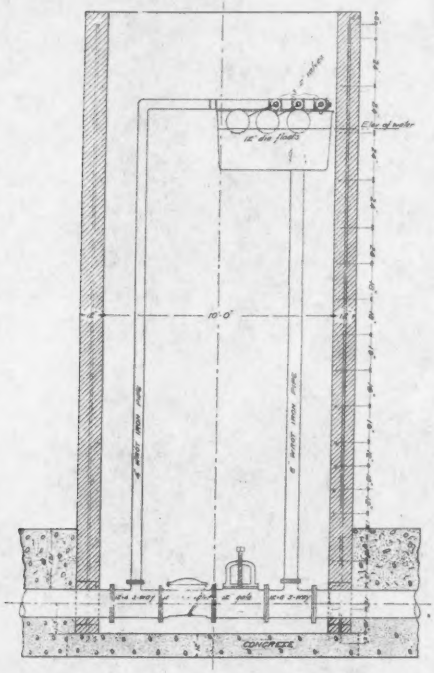
The material for the reservoir cost as follows: Cement, $3 082; paving blocks, $946; valves, $218; lumber, $474; a total of $4 720 for material, or $3 774 not including the paving blocks, which were purchased and used merely to give the slope a neater appearance. This reservoir is an example of low-priced construction where labor cost nothing and time is of minor consideration.

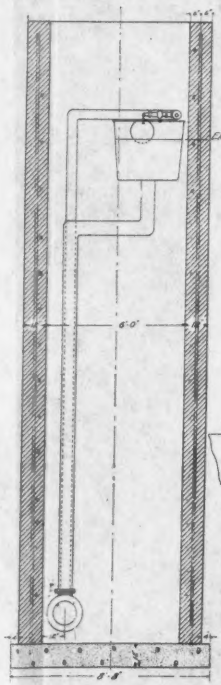
Plate XV shows the plans of the reservoir.

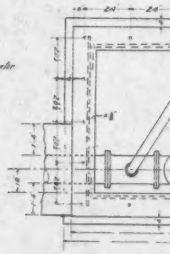
THIRTY-INCH CEMENT-LINED PIPE.

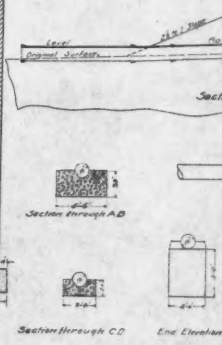
In 1900, it became necessary to remove and relay with cast-iron pipe about 850 ft. of the 30-in. cement-lined wrought-iron pipe which was laid into Charlestown in 1870. The reason for relaying was in no way caused by a failure in the old pipe, part of which is









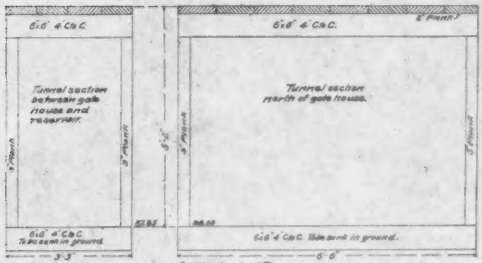


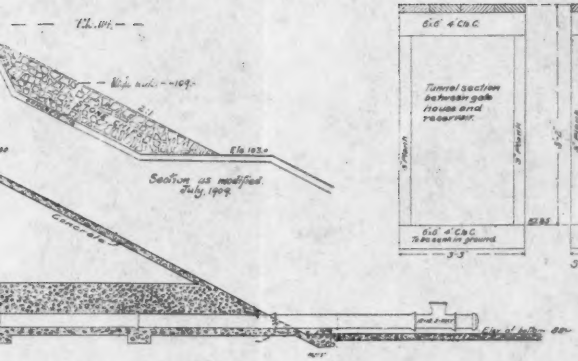
NOTE. Red lines show twisted 6" Steel Rods.

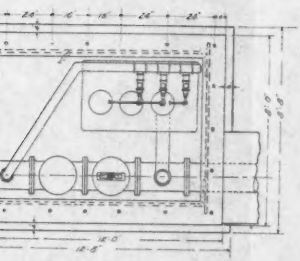
Scale 1"-1'

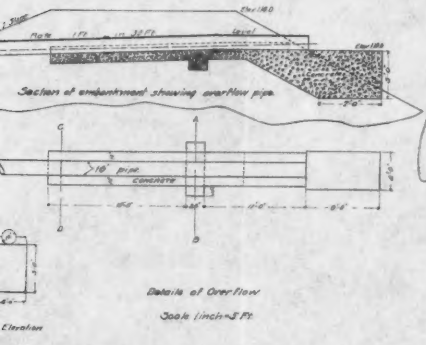
THE DEER ISLAND R

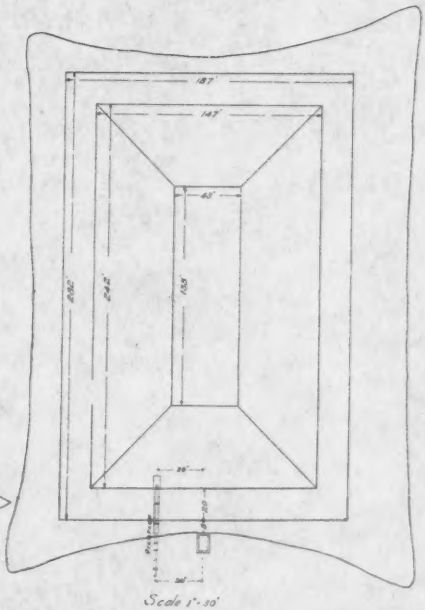
DEER ISLAND TUNNEL.
Method of bracing.


6'6" c to c
6'6" c to c
Tunnel section between gate house and reservoir.
Tunnel section north of gate house.
3" Plank
6'6" c to c
Scale 1 inch = 1 ft.









D RESERVOIR.

still in use and which, when laid in unyielding soil, has given good satisfaction. In constructing this pipe three 3-ft. lengths were joined in the shop. Over both of the riveted joints a clamp sleeve of proper curve section was placed, the space between the sleeve and the outside surface of the main being filled with neat cement. These 9-ft. lengths were joined together in the trench by a close-fitting sleeve 8 in. wide. The outside of the pipe was covered with 2 in. and the interior was lined with $1\frac{1}{4}$ in. of cement. The

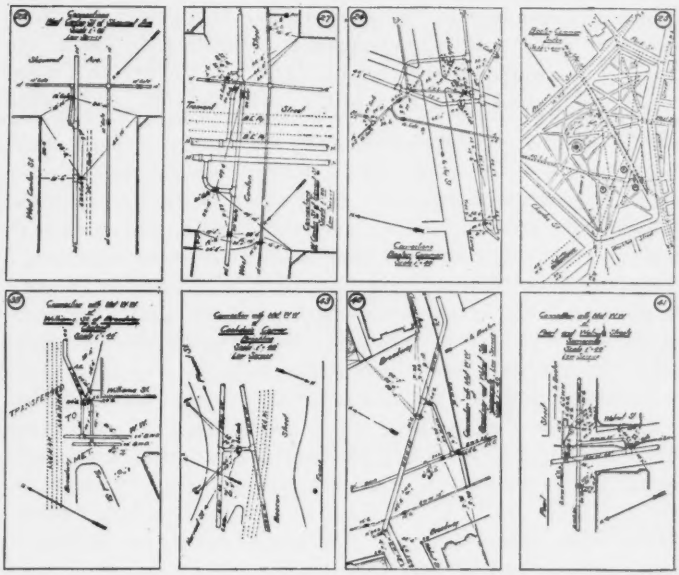


FIG. 13.
VALVE LOCATION BOOK.

wrought-iron composing the pipe was 0.16 in. thick, and in spots had rusted to 0.11. The cement removed seemed extremely inert.

PIPE TO SPECTACLE ISLAND.

During the present year a line of 4 000 ft. of 4-in. pipe, with Ward flexible joints, was laid connecting Long and Spectacle

islands. The 12-ft. lengths weighed 330 lb., requiring 18 lb. of lead per joint. A cradle 115 ft. long, resting on the bottom of the harbor, was used, in which to lay the pipe, the water being 28 ft. in depth a portion of the way. Plate XIV, Fig. 2, shows the manner of laying the pipe from the scow.

Fig. 13 shows a few sheets of a book of eighty or more pages, giving locations to gates on important lines for the use of those who are compelled to find them at any time.

As some portions of the matters referred to in this paper have previously appeared in *Engineering News*, the author desires to thank them for courtesies extended in permitting the use of the same. The author is also under obligation to the Boston Transit Commission, and to Mr. Edwin C. Hayden for photographs loaned.

USES AND ABUSES OF WATER FILTRATION.

BY GILBERT H. PRATT, CHEMIST OF THE RHODE ISLAND STATE BOARD OF HEALTH.

[*Read December 11, 1912.*]

In connection with the uses of filtration of water, the author would first mention a few of the conditions which call for such treatment. For many years a town or city may have been using some water of comparatively good appearance as a supply when suddenly there appears an unusual amount of typhoid fever among the people. Investigation demonstrates that it is the water supply which is common to these cases, and bacteriological tests prove that the water of the stream is polluted. Further investigation shows that there have been some cases of typhoid in a small village upstream, which has no sewage purification, and the excreta from these cases has found its way into the water supply of the downstream neighbor. This experience — such a common one in the case of cities and towns taking their supplies from streams which have an increasing population on the watershed — leads to a full appreciation of the need of purification, and the resulting improvement in the supply with attendant betterment of the health of the community serve as evidence of one use to which filtration is put.

Another city may be enjoyin , an exceptionally good health record, especially as to typhoid fever, but the presence of a large amount of organic matter, giving the water a high color and a vegetable taste, causes criticism of the supply, and, regardless of analyses as to its sanitary purity, a large number of citizens persist in the contention that the supply is not what an up-to-date city should be furnishing, until finally it is decided to filter the water by mechanical filtration in order to get a water of better appearance. The criticism above referred to immediately ceases, and the people receive a practically colorless water with comparatively no taste in place of the old familiar "organic brew."

Thus esthetic reasons may in many cases be sufficient cause for filtration, and the resulting output certainly justifies its use in these cases.

Similar to the above instance, the presence of different algæ may be the cause of disagreeable odors and tastes which demand filtration by methods which in such cases usually require aëration in conjunction with either double slow sand filtration or mechanical filters.

Some cities or towns and numerous small private supplies have been troubled, in cases where the supply is from driven wells, by the presence of iron in the water. This iron often exists in the lower state of oxidation or ferrous condition and upon contact with the air separates from the water as a " brick dust " sediment. Such supplies as this can be purified by methods involving aëration and oxidation of the iron before filtration or in the case of smaller supplies this has been successfully done by the use of a patented double filter which utilizes sand and animal charcoal.

Many industrial processes, especially bleaching and dyeing, require water of good color, low in iron, and free from turbidity. This requirement has resulted in the installation of a large number of filter plants, and the use of filtration for these purposes has been invaluable to numerous mills of this and other countries.

A great many times filtration is resorted to largely, if not entirely, to remove turbidity from the water. This is true of many western waters.

Having thus brought out different conditions which call for the use of filtration, the author will now cite certain concrete instances of installations which have been made for the different reasons above mentioned, and will present results which will show the efficiency of such plants when properly operated in improving the objectionable features which they were primarily installed to remove.

As instances of purification of supplies which have at times, prior to the use of filtration, been the cause of typhoid fever, — or, in other words, as instances to illustrate filtration for removal of bacterial pollution, — we may cite Lawrence, Mass., and Providence, R. I. The Merrimac River receives sewage pollution at Lowell and at many other points above Lawrence, and its

average bacteriological condition during 1910, to cite one typical year,* as received on to the filters, was a total count of 9 100 bacteria per c.c., and the colon bacillus, which is taken as evidence of the presence of sewage contamination, was present in all the samples examined in 1 c.c. tests. The output from the plant (old filter) showed only 57 bacteria per c.c. and the test for B. coli communis was positive in only 8.3 per cent. of the samples examined in 1 c.c. tests. This shows a removal of 99.4 per cent. of the bacteria and a very marked improvement of the conditions as to the presence of B. coli communis.

The water supply of Providence is obtained from the Pawtuxet River, and prior to the year 1906 was used without filtration. During these years there were at least two typhoid-fever epidemics which were traceable directly to contamination of the drinking supply of the city. The first was in 1882 and the second in 1888, the latter epidemic being caused by the fact that the attendants upon a case of typhoid fever had considered the river a means of quick disposal of the fecal matter of the patient.

Agitation for purification immediately followed this last epidemic, but it was a number of years before the type of filter could be settled; but finally, in 1902, the contract was let for slow sand filters, and beginning with 1906 the city was furnished with filtered water. The results were noted at once, not so much from the standpoint of color, — for as is the case with this type of filtration only a comparatively small per cent. of color is removed, — but by the freedom of the water from turbidity and sediment and by a reduction in the organic matter which had caused a marked vegetable odor and taste. Beside the visible improvement in the supply, the analytical study of the conditions before and after filtration showed the changes which were effected, and the excellent sanitary condition of the supply.

As an indication of the work which these filters have performed, I would present (Table 1) the following figures showing the average condition of the river as to appearance, color, and bacteria for four years from 1902 to 1905 inclusive as shown by bi-monthly tests made by the Rhode Island State Board of Health, and for comparison similar figures on samples taken from a tap in the city

* Massachusetts State Board of Health Report 1910, page 273.

covering the same period. These figures show that during this period the distribution system and reservoir storage effected some purification as shown by the slight improvement in the appearance, a removal of 10.9 per cent. of color and 81.8 per cent. of bacteria. Tests for B. coli communis were not made by the Board at this time.

TABLE 1.

PROVIDENCE WATER SUPPLY.

(1902—1905.)

Source.	No. of Samples.	Average Turbidity.	Average Sediment.	Average Color.	Average Bacteria per c.c.	Remarks.
Intake.	96	Slight to decided.	Considerable.	46	4,000	
Tap in city.	96	Very slight to slight.	Slight.	41	730	After reservoir system and distribution.
Per cent. removal.	—	Appreciable.	Appreciable.	10.9	81.8	

(1906—1911.)

Source.	No. of Samples.	Average Turbidity.	Average Sediment.	Average Color.	Average Bacteria per c.c.	B. Coli in 10 c.c. tested. Per Cent. of Samples.	Remarks.
Intake.	144	Slight.	Slight to considerable.	48	2,525	92	
Tap in city.	144	None.	None to very slight.	28	60	1.7	After filtration, reservoir system and distribution.
Per cent. removal.	—	Complete.	Almost complete.	41.7	97.5	—	

Similar figures are also presented (Table 1) showing the average condition of the river for six years subsequent to the use of filtration covering the years 1906 through 1911, and similar figures from a tap in the city for comparison. These figures show a

marked improvement in the appearance of the water, a 41.7 per cent. of removal of color, as compared with only 10.9 per cent. due to the reservoir system prior to filtration, which would indicate 30.8 per cent. due to the filters themselves, and show a removal of 97.5 per cent. of the total number of bacteria present. B. coli communis was found to be present in 92.0 per cent. of the number of samples tested on the river, and in only 1.7 per cent. of those taken in the city during the filtration period, these tests being on 10 c.c. samples.

In the preceding tables one sample has been omitted in striking the bacterial averages for the tap in the city during the six years of filtration because of the fact that certain conditions which will be brought out later required the use of river water which affected that sample. The figures presented, therefore, are a true measure of the water of the city during filtration, and show the good work which has been accomplished in removing the bacterial pollution from the water.

The water supply in East Providence is taken from the Ten Mile River, which is a polluted stream receiving sewage from Attleboro, Mass. The condition of this river became such that in 1899, upon the recommendation of the State Board of Health, a mechanical filter plant was installed. The results have been highly satisfactory, showing a reduction from 8 160 bacteria per c.c. in the river to 33 per c.c. in the effluent, or a removal of 99.6 per cent., and complete removal of B. coli communis at all times. These analyses were of monthly samples taken the first eleven months of this year. In addition to this efficiency for bacterial removal, the plant at the same time reduced the color from 61 in the case of the raw water to 6 in the filtered water, or a removal of 90.1 per cent.

From the above, it has been plainly shown what can be accomplished by either slow sand filtration or mechanical filtration in removing dangers from bacterial pollution of water supplies, and it would seem to indicate very little choice between the two systems from the standpoint of removals effected, but with the advantage in favor of mechanical filtration from the standpoint of removal of color from water high in organic material. I will not attempt to go into a discussion of the relative merits of these

two systems of purification, as that is not the subject of this paper, but I will simply say that each system is efficient under certain conditions, and local conditions should, in all instances, assist in the selection of one or the other method.

As an instance to illustrate the use of filters for removal of color, I would cite the case of the plant at East Warren, R. I., where during 1911 the color in the raw water averaged 74, and was reduced by the mechanical filters to 11, or a removal of 85.1 per cent. This plant is an illustration of a case where slow sand filters, while they would have delivered a sanitary output, in a short time would have experienced trouble from algæ present, and the output would not have given satisfaction to the consumers because the water would still have been highly colored instead of being practically colorless as is the present condition.

At Newport, R. I., there is a mechanical filter plant which has been installed to serve a double purpose of removing bacterial pollution and also to remove odors due to algæ. This is an up-to-date plant in every way, using a system involving aëration, coagulation, and sedimentation, followed by filtration and then disinfection of the supply with hypochlorite of lime. The color of this water is comparatively low, and the resulting output is of good appearance, when the plant is being operated up to its possibilities, and the effluent is largely free from algæ and odor troubles. Likewise, the water is reduced as to bacterial count to a point where it is practically sterile.

Next passing to the question of concrete instances of installations for the removal of iron, I would mention the plant at Marblehead, Mass., where by the use of aëration and filtration through sand the color of the water is improved from a rusty appearance to a practically colorless water, and the iron is reduced from 4.70 parts per million to .06 parts, or a removal of 98.7 per cent. One installation has come under my personal observation where the particular apparatus above referred to, which employs a double-cylinder filter using sand and animal charcoal, showed a removal of iron from 8.00 parts to .10 parts, or 98.75 per cent. removal, with accompanying improvement in the appearance of the water.

In connection with the use of filters in the purification of water

for industrial purposes, I would say that I have been in touch with a number of installations where mechanical filters have been installed of different types which, when properly operated under proper supervision, turn out a product which gives entire satisfaction and shows purification in every way comparable with the results above given.

In treating the second part of my subject, namely, the abuses of water filtration, I would call attention to a number of ways of abuse which might lead to criticism of the whole idea of filtration, but in citing these cases where such abuses have occurred, for obvious reasons I will refrain from naming the installations in most cases.

In the case of slow sand filtration, one would consider it an abuse to attempt to purify a water high in algæ content which would result in clogging of the beds and a general upsetting of operating conditions at the plant. Of course, double slow sand filtration, especially if in connection with aëration, would qualify this previous statement, as aëration and a pre-filter would put the water in condition where it could be handled by the secondary filters, but where aëration followed by coagulation and sedimentation and filtration by mechanical filters would obviate all of the trouble due to clogging of the beds, it would seem as if it was abusing the at times satisfactory method of slow sand filtration to attempt to handle such a water by simple slow sand filtration.

It would also seem an abuse of this method to use it in connection with filtration of highly colored water, which would subject the method to criticism on account of the unsatisfactory appearance of the output.

Another abuse of this method in connection with operation of the filters is too quick changing of rates of operation, which tends to disturb the bacterial action going on at the surface with attendant poor results from an analytical standpoint. Also attempting to overcrowd the filters by running at too high rates is a practice which is sometimes met with, which results in diminution of the efficiency of the plants.

A slow sand filtration plant which would handle a given water satisfactorily might, as was the case in Providence, be installed without covering the beds. Such an installation as this in this

section of the country is certainly an abuse of the method, for the result invariably would be what was found in Providence, that as soon as a hard winter struck the plant the beds would become covered with ice and it would be impossible to get at the surface to clean without removal of the cakes of ice. This condition occurred in Providence for a short time during February, 1907, finally necessitating opening the river gate, and the use of raw water for about two weeks or so before the weather moderated and before the ice could be removed. This experience resulted in steps immediately being taken to cover the beds, and this experience should serve as a lesson against such open installations in this section of the country.

In connection with slow sand plants, it is necessary to have competent help administering the plant, and one of the easiest ways to abuse a plant is to put it into the hands of inexperienced operators.

The above remark about labor in connection with plants is especially true in the case of mechanical filters where the supervision must be particularly close and where tests for color and alkalinity must be made to regulate the doses of chemicals used.

One of these plants which has come under my observation had operated for a number of years satisfactorily, turning out a water which had given entire satisfaction in connection with work in a bleachery. When I was consulted with regard to difficulties which were occurring, I found that the only trouble was that the parties in charge did not have an understanding of the question of alkalinity control of the plant, and the residual alkalinity of the effluent had dropped to a point where the water was passing the plant at times in an acid condition, or at best with an extremely low alkalinity, resulting in after-coagulation in the vats and throughout the system. This condition had been caused by the fact that a certain mill above them had been discharging a larger amount of acid wastes in the river than at the time their formula for operating was figured for them. Not knowing how to vary the dose from time to time, they had stuck to the old formula with the resulting poor work until corrective measures were taken. The addition of alkalinity to the water put the plant back into its former good condition.

At another installation concerning which I had been consulted, I found another condition which was causing trouble. The responsible man in charge of the plant for some reason or other was assigned to night duty, and he was attempting to make his control tests for color and alkalinity at night by artificial light. This, of course, gave far from accurate results. Another trouble at this plant was that the one man was expected to operate the flow of chemicals from the tanks which were located in the pump house and at the same time attend to washing the filters in a filter house which was located about one eighth of a mile away. This spreading out of the plant made it impossible for the lone operator to properly attend to the dosing, and the result was that the flow of chemicals varied from time to time, with resulting poor output from the plant. Here, too, I found trouble in connection with the dosing, for the formula they were using to operate by had evidently been recommended without a knowledge of the water to be handled, and they too were operating with a too low residual alkalinity.

At another plant this same trouble as to a low residual alkalinity was found to exist, and the output contained undecomposed sulphate of alumina. Investigation showed that this operator was using an indicator solution many times too strong, and the alkalinity tests which he was obtaining were absolutely inaccurate. They also were not showing intelligence with regard to the necessity of increasing the doses of chemicals to meet varying conditions in the raw water. Corrective measures, recommended by the State Board of Health, and instruction of the operator, has resulted in this plant turning out one of the best outputs in our state at the present time.

At still another plant the biggest difficulty discovered when troubles arose seemed to be with the application of the chemicals, which in this plant required an extremely close control on account of an influence on the color of the filtered water as the residual alkalinity became too high. The engineer who was employed when this plant started was a man who had been for years pumping water out of the reservoir under the old system, and he could not be made to realize that careful supervision was necessary, and grossly neglected controlling the flow of the chemicals. These

operating troubles immediately ceased when a new, competent engineer was put in charge of the plant.

The effect of an abnormal amount of organic matter or algæ in comparison with the color of the water sometimes has resulted in an under dosing with coagulant, as this additional amount of organic matter has seemed to prevent proper coagulation with resulting incomplete removal of the constituents which it was intended to remove, and the effluent has contained alumina and abnormal amounts of color and algæ. Proper dosing in view of the above-mentioned conditions has resulted in excellent work from this plant.

Another abuse is oftentimes attempting to operate a plant, with every possibility for good results, by methods which some man of limited experience may have used at some other plant, meeting entirely different conditions. Such cases have occurred under my observation, but have been capable of adjustment when instructions have been given which had in mind the type of plant and the raw water to be handled.

In connection with the operation of plants of the mechanical type, it is essential that the night man should be one who can be depended upon to stay awake, as a nap for an hour or two may result in throwing the whole operation of the plant out of adjustment for several hours. I have had my experience with this trouble.

Having thus brought out the conditions which call for filtration of water supplies and having shown the good results obtained with certain installations, I have also attempted to point out a number of ways in which filtration plants are at times abused. One or more instances of abuse are sometimes the only cases of filter plants coming to the attention of some people who immediately condemn the possibilities of the whole proposition of water purification on this meager knowledge.

I would take this opportunity to warn you water-works men against such conclusions from knowledge of some plant or plants which may not be doing all that has been claimed for them. I would also particularly caution that you do not take the cases of abuse which I have mentioned as indicative of any lack of confidence on my part in the ability of plants to purify water satis-

factorily when the following essential points have been observed: first, have the choice of the system and the general outline and construction of the plant in the hands of competent consulting engineers who are experts in these matters; next, having obtained the plant properly constructed and designed to handle the water to be filtered, obtain the best possible men to oversee and run the plant after instruction from competent specialists, and if trouble occurs, call in advice to straighten out the difficulty instead of experimenting blindly; and last, throughout the whole operation of the plant bear in mind that you are handling an efficient machine capable of results, and not an automatic affair which can be left to its own resources.

DISCUSSION.

MR. CHARLES W. SAXE.* I have been troubled quite a little with algæ during the summer months. The principal trouble has been from the stoppage of the beds, due, I think, to the use of too little alum, and I increased the amount to remedy that difficulty. Otherwise the results have been excellent. The plant is now delivering practically sterile water, as Mr. Pratt says. I very seldom find coli in the raw water, and I have never yet found it in the effluent.

The efficiency of a plant of the rapid type most assuredly depends upon the even running of the coagulant in proper proportion to the flow of raw water. Slap-dash doses of the coagulant do not prove out very well, especially with water containing algæ, dead or alive. For uniform bactericidal action, the hypochlorite solution must also be run at an absolutely even rate.

Outside of these necessities and the correct estimation of dosings, there are few other vital things for efficiency.

MR. R. S. WESTON † (*by letter*). Mr. Pratt, in his capacity of chemist of the Rhode Island State Board of Health, has had perhaps a better opportunity to observe the operation of various sorts and kinds of water purification plants than any other man in a similar position. While there are practically no muddy rivers in Rhode Island, there are many polluted ones, besides

* Chemist in charge of Filtration Plant, Newport, R. I.
† Sanitary expert, Boston, Mass.

sources which are contaminated with growths of algæ, other microscopic plants and animals, and with the wastes of the most densely populated state in North America. That Mr. Pratt has not neglected his opportunity, this paper is an evidence.

It is well to emphasize again Mr. Pratt's advice as to the necessity of designing a plant to suit the water to be purified and not in accordance with some general "cure-all" theory which may have no bearing in the particular case; also his insistence upon careful and responsible operators of filters and the analytical control thereof. There are few states, however, where advice is so freely and promptly given as in Rhode Island, and to the writer's knowledge this efficiency has kept at least one filter plant from failure.

Mr. Pratt mentions many of the abuses of filtration and has covered the ground. In connection with the removal of algæ, however, he does not mention the use of intermittent filters such as were used at Springfield. Here, as is well known, experiments demonstrated that any single system of filtration was inadequate to remove taste and odor. It was because of this experience that the writer thought that intermittent sand filters with aëration were best suited for the purification of the Newport supply, grossly contaminated with algæ, and he still believes that without the use of hypochlorite the operation of the present mechanical filters would be impracticable, although with it they present some advantages.

The writer had one experience with double filtration through sand and charcoal in 1895, at Asbury Park, N. J. These filters were used for the deferrization of the water, and it was found that at times iron was absorbed by the charcoal filter and at times given off. The charcoal was replaced with sand, and results were obtained equal to the best — and far better than the average with charcoal. New charcoal, however, removed more iron than new sand.

Most water purification experts spend half their time in correcting the errors mentioned in this timely paper, which, if read and taken to heart as it deserves to be, will tend to prevent many of the mistakes of the past and conserve the public energy in the future.

MR. H. W. CLARK * (*by letter*). I have little comment to make in regard to the main part of Mr. Pratt's paper. We all know at the present time that there is a place for slow filters and a place for rapid filters with the use of coagulants, and the paper brings out forcibly many points in regard to correct operation of filter plants.

I think, however, that he is incorrect in his statement that it is "an abuse to attempt to purify [by a slow sand filter plant] a water high in algæ content, which would result in clogging of the beds and a general upsetting of the operating conditions at the plant." While I have had a considerable acquaintance with reservoirs in which enormous growths of microscopical organisms occur from time to time, the two most prominent in this respect in my mind are the Ludlow Reservoir, a part of the water supply of Springfield, Mass., and the reservoir of the water supply of South Norwalk, Conn. Both of these waters have been successfully and economically filtered by slow sand filter plants; that at Ludlow by single sand filters, and that at South Norwalk by double sand filters. Experiments made at Ludlow by the State Board of Health, and afterwards by the Springfield Water Board, with Fuller and Gray as consulting engineers, ten or more years ago, showed clearly that sand filters were much more efficient in the removal of organisms, tastes, and odors than mechanical filters when handling such waters, and following these experiments, the sand filters mentioned above were installed at Springfield, and about the same time the sand filters were built at South Norwalk, Conn. Both plants have been absolutely efficient and economical when filtering two reservoir waters seriously polluted with microscopical organisms.

Mr. Pratt says also that it is "an abuse of this method [slow sand filtration] to use it in connection with a highly colored water on account of the unsatisfactory appearance of the output." As a matter of fact, this statement needs some qualification. Two of the most highly colored waters purified by filtration in New England are the reservoirs just mentioned. At times in the summer months, the colors of these reservoirs approach or exceed 100, but owing to the nature of this coloring matter and the presence of iron in the water, more than 80 per cent. of it is

* Chemist, Massachusetts State Board of Health.

often removed by single slow sand filtration, and at South Norwalk, double filtration produces a practically colorless water. With the ordinary highly colored river or swamp water, Mr. Pratt's statement is, of course, much more true.

MR. GEORGE C. WHIPPLE* (*by letter*). The writer has been very much interested in Mr. Pratt's paper. Papers of this character need to be published about once in so often in order that the importance of proper operation of filters may be kept fresh in our minds. One of the things that sanitary engineers most lack is adequate information in regard to the results obtained by different filter plants under the special conditions under which they operate. The New England Water Works Association has done a good work in standardizing reports of various kinds, and the writer would be glad to see this subject taken up by an appropriate committee, and studied with a view to standardization of the results of filter operation.

One point mentioned by Mr. Pratt is of particular interest, namely, that the filtration of the Pawtuxet River water by the Providence sand filter removes the vegetable odor of the water, although it does not decolorize it. This suggests that the vegetable odor may be due more to the suspended and collodial matter than to the organic matter in solution. If Mr. Pratt could furnish further information in regard to this matter, it would be of interest to many of us.

MR. PRATT (*by letter*). Taking up a few points raised by Mr. Clark, I would say with regard to his comments upon my remark in connection with removal of color, that I had in mind handling a reservoir which at times goes up to 180 in true color, and in this case slow sand filters were considered for a time as a means of purification. I consider that it would have been an abuse of slow sand filtration to have tried it with this water or with waters even approaching 100 in color. I think also that Mr. Clark unintentionally misleads somewhat in his mention of 80 per cent. color removal by slow sand filtration. My experience in removal of true color has been that 30 to 40 per cent. is considered extremely good for the method. Of course, with algæ-infected or iron-bearing

*Professor of Sanitary Engineering, Harvard University, and Consulting Engineer, New York.

waters having a high apparent color in comparison with the true color, removals of apparent color might easily give higher figures.

As to Mr. Clark's criticism of my statement in regard to the treatment of algæ-infected waters, I would say that, in my complete statement on this matter, I was careful to state that the use of mechanical filters for this purpose should be in conjunction with aëration, coagulation, and sedimentation, and with this system efficient work in removal of color, odor, and taste can be accomplished. Also, I stated that double slow sand filtration especially in connection with aëration might be used. When making the statement that single slow sand filtration would not be efficient I had in mind statements to be found in the reports of the Massachusetts State Board of Health for 1901 and 1905, in connection with the Ludlow Reservoir of the Springfield supply, and there, if I am not mistaken, the position of that board as the result of experimentation was very conservative as to the ability of single slow sand filtration to handle this water at times of extreme algæ content. In fact, they advised against the use of this water as a supply even after filtration. I also had in mind accounts of clogged beds at South Norwalk, Conn., which had come to my attention. If Mr. Clark has now been successful in accomplishing good work at South Norwalk it bears out my statement that double slow sand filtration might be efficient in the case of "algæ" waters, and if the Ludlow Reservoir water has been efficiently handled by single slow sand filters, I think that with waters of that type such a case would be the exception rather than the rule.

With regard to the point raised by Mr. Whipple as to the removal of vegetable odors by the Providence filters, I would say that while these odors are reduced very perceptibly, the filtered water still has a distinct vegetable odor practically all the time. I think the point raised by Mr. Whipple that the reduction is possibly due to removal of suspended and colloidal matters may, in part, account for the reduction, although I think that some of the improvement is due to the reduction in the organic matter in solution, which is materially reduced by the filters as shown by albuminoid ammonia tests and oxygen consumed determinations, as well as by the color removal of 30.8 per cent.

CONSTRUCTION OF ARCHED MASONRY DAM AT LAS VEGAS, NEW MEXICO.

BY WILLIAM T. BARNES, CHICAGO REPRESENTATIVE OF METCALF AND EDDY, CONSULTING ENGINEERS.

[*Read December 11, 1912.*]

Las Vegas, the second largest city in our newly adopted state of New Mexico, is situated in the northeastern part of the state along the foothills of the Rocky Mountains, on the Pecos-Arroya and Gallinas rivers, at an elevation of about 6 500 ft. above sea level.

The census of 1910 showed a population of 7 300 as against 6 320 in 1900. The future population, dependent on conditions other than local ones, is difficult to forecast.

The main line of the Atchison, Topeka & Sante Fé Railroad passes through the eastern portion of the city and makes Las Vegas one of its principal division points. It is therefore an important railroad center, distributing supplies to a large tributary area, shipping in turn the products of a large rural district.

The agricultural interests are important, and with the inauguration of large irrigation projects which have already been undertaken by private enterprise, rapid progress should be made in the development of the natural resources of this community. It is anticipated that large beet sugar industries and other industrial enterprises will follow the introduction of irrigation works. It will not be surprising, therefore, if the next decade shows a more rapid increase in the population of this city than did the last.

Las Vegas has already adopted many modern ideas of city planning. In the newer part of the city the houses are built upon substantial lines, well set back from the street on large lots, surrounded by handsome and well-kept lawns dotted here and there with rapid-growing trees.

Although the finances of the city have not as yet permitted of building modern pavements to any considerable extent, the entire city is well provided with modern granolithic sidewalks separated from the curb by wide areas of sod, in which are planted quick-growing shade trees, thus presenting a very attractive and enterprising appearance.

Water Supply.

Water is supplied to the community by the Agua Pura Company. The source of the supply is the Gallinas River at a point about nine miles north of the city, in the narrow confines of the Gallinas Cañon. The Agua Pura Company is also a dealer in ice, which it furnishes not only to the local community, but also to the Atchison, Topeka & Santa Fé Railroad, the needs of which it supplies for several hundred miles in either direction from Las Vegas. It has built nine dams in the bed of the Gallinas River for the purpose of ice production. In one of the reservoirs thus produced, known as No. 8 reservoir, is located the water-works intake. From this intake the water flows through an open canal along the borders of the reservoir, for a distance of one-half mile, where it enters a small settling basin, where racks and screens protect the inlet to the main supply pipe. From this point, which is at an elevation of 410 ft. above the general city level, the water flows 5.1 miles through a 12-in. pipe to a distributing reservoir two miles north of the city and at an elevation of approximately 281 ft. above the city level. From this reservoir the water is distributed to the pipe system of the city by two circuits, thus insuring the city ample pressure, and safety in case of need of repairs to either of these pipe lines.

Drainage Area.

The drainage area tributary to the intake is about 90 sq. miles, as determined from the topographical maps of the United States Geological Survey.

Records of Rainfall.

With exceptions during the years 1890 and 1891 only, the government record of monthly and yearly precipitation in the city of

TABLE 1.

MONTHLY AND YEARLY PRECIPITATION, EAST LAS VEGAS, NEW MEXICO.*

Year.	Jan.	Feb.	March.	April.	May.	June.	July.	August.	Sept.	Oct.	Nov.	Dec.	Annual.
1892	1.22	0.07	1.72	0.41	0.54	1.01	2.28	0.79	0.48	1.31	0.05		
1893	0.18	1.06	0.07		1.50	0.25	5.64	6.97	3.87	0.04	0	0.31	19.99
1894	0.10	1.66	0.04	0.54	2.53	2.82	2.89	4.05	1.22	0.08	0	0.28	16.21
1895	1.00	1.85	0.30	0.52	4.02	1.98	6.85	5.32	T	1.12	0.88	0.82	24.66
1896	0.19	0.32	0.83	1.00	0.11	2.02	3.87	2.13	4.38	4.35	0.02	0.51	19.73
1897	0.69	0.70	1.43	0.37	6.63	1.23	1.18	3.29	0.79	1.94	0	0.59	18.84
1898	0.51	0.21	0.49	1.41	1.04	2.74	4.63	2.97	1.29	0.33	0.57	0.80	16.99
1899	T	0.73	0.70	0.21	0.40	2.65	7.09	0.17	2.87	0.52	0.43	0.09	15.86
1900	0.19	0.25	0.59	2.25	1.87	3.59	2.70	2.23	4.27	1.98	0.30	0.46	20.68
1901	0.27	0.70	0.14	1.17	5.55	0.19	3.70	4.95	2.00	1.40	1.78	0.30	22.15
1902	0.10	0.10	0.01	0.06	1.95	0.30	1.91	1.83	1.33	0.47	0.79	0.93	9.78
1903	0.07	1.42	0.13	0.52	0.22	6.24	1.41	3.57	1.11	0	T	0.12	14.81
1904	0.20	0.20	T	0.24	0.97	3.20	4.95	0.68	6.07	1.08	0.05	1.10	18.74
1905	1.45	1.84	2.13	3.07	2.04	1.56	1.70	1.34	4.25	0.48	3.32	0.68	23.86
1906	0.04	1.02	0.47	2.17	1.08	2.80	7.82	1.97	1.86	1.67	0.86	1.32	23.08
1907	1.57	0.01	0.07	2.13	2.57	0.77	5.57	3.30	0.22	0.82	0.77	0.20	18.00
1908	0.14	1.05	0.05	1.12	0.68	1.13	2.71	9.24	0.06	0.76	0.96	0.26	18.16
1909	0.17	0.49	1.00	0.50	0.51	0.51	1.53	5.99	3.91	0.76	0.19	0.44	16.00
1910	0.16	0.30	0.61	0.98	0.13	0.31	2.48	3.72	1.08	0.85	0.45		11.07
1911	0.11	1.33	0.18	0.93	2.41	2.44	3.55	2.30	0.68	2.83	0.30	0.93	17.99
Average	0.42	0.77	0.55	1.03	1.84	1.89	3.72	3.34	2.09	1.14	0.59	0.56	18.00±

* From Weather Bureau Reports, New Mexico Section.

TABLE 2.

MONTHLY AND YEARLY PRECIPITATION, GALLINAS PLANTING STATION, NEW MEXICO.

Year.	Jan.	Feb.	March.	April.	May.	June.	July.	August.	Sept.	Oct.	Nov.	Dec.	Annual.
1908	0.56	1.53	1.30	3.23	1.05	0.58	5.10	5.71	0.28	1.09	1.13	0.44	22.00
1909	0.69	0.61	1.54	0.55	0.66	1.71	5.11	6.98	2.86	1.07	0.97	0.66	23.41
1910	0.62	0.76	0.65	1.63	1.54	2.49	5.59	3.96	1.86	1.27	0.69	0.42	21.48
1911	1.00	1.91	0.72		2.54	1.20	9.01	2.38	0.61	3.42	0.82	0.98	24.59
Average	0.72	1.20	1.05	1.80	1.45	1.49	6.20	4.76	1.40	1.71	0.90	0.63	22.37

TABLE 3.

MONTHLY AND YEARLY PRECIPITATION, HARVEY'S UPPER RANCH, NEW MEXICO.

Year.	Jan.	Feb.	March.	April.	May.	June.	July.	August.	Sept.	Oct.	Nov.	Dec.	Annual.
1910	1.42		1.18	2.70	1.29	2.31	3.87	6.56	1.92	2.43	0.87	1.60	26.15
1911	1.20	3.04	2.03	2.13	2.70	3.80	8.32	3.08	2.05	6.86	1.20	1.68	38.09
Average	1.31	?	1.61	2.41	2.00	3.05	6.10	4.82	1.98	4.65	1.04	1.64	32.12

Las Vegas is continuous since the year 1889, as recorded in Table 1. From these records it appears that the average yearly rainfall is about 18½ in., the maximum being 24½ in., the minimum slightly less than 10 in. The bulk of the precipitation occurs during the so-called "rainy season," which includes the months of July and August, and sometimes parts of June and September.

Records of precipitation were kept at the Las Vegas Hot Spring from June, 1898, to July 1903, but the omissions in the records are so frequent as to prevent their satisfactory use.

At the Gallinas Planting Station in the Gallinas valley, a few miles above the water-works intake, the records have been systematically preserved since January, 1908, as recorded in Table 2, while at Harvey's Upper Ranch near the headwaters of the Gallinas River the records, with exception of one month, have been kept with regularity since January 1, 1910, and are recorded in Table 3.

The short periods during which the records have been maintained prevents the drawing of accurate conclusions, but are sufficient to show that the amounts of precipitation increase with the elevation, especially during the winter and spring months.

This increased precipitation is mainly in the form of snow, which melts gradually during the spring months, the run-off accordingly tends to be more evenly distributed during the spring and early summer.

Yield and Its Variation.

The United States Geological Survey has maintained a gaging station on the Gallinas River at the Las Vegas Hot Springs about 7 miles above the city of Las Vegas and about 2 miles below the intake of the water works, since August, 1903, and these records are available to and including the year 1910.

The records for the year 1904 show that, prior to the storm and flood September 29 to October 1, there was practically no flow in the stream, and after the flood subsided there was but a slight flow.

In Table 4 are recorded the minimum and mean rates of flow in million gallons per day for each month, and by years from 1905 to 1910 inclusive. From this table it appears that there have

TABLE 4.

DISCHARGE OF GALLINAS CREEK AT HOT SPRINGS, N. M., SIX MILES ABOVE LAS VEGAS, N. M.*

	Minimum Rate of Discharge, Mil. Gal. Day						Mean Rate of Discharge, Mil. Gal. Day.					
	1905.	1906.	1907.	1908.	1909.	1910.	1905.	1906.	1907.	1908.	1909.	1910.
January	7.7	2.6	4.6	0.8	1.2	1.2	7.7	5.9	8.8	1.9	2.8	3.2
February	7.7	5.2	9.0	0.8	1.2	1.2	25.8	7.2	9.6	3.6	2.6	2.8
March	36.8	9.0	9.0	2.3	2.2	3.2	60.3	16.7	17.8	4.6	7.5	13.8
April	48.4	33.2	16.1	2.3	3.2	6.8	114.2	63.7	28.1	19.0	15.1	19.7
May	78.1	41.3	35.5	12.9	9.7	3.2	133.0	71.0	59.0	17.7	15.9	14.1
June	12.9	5.2	9.0	2.6	1.3	0.2	40.9	20.3	41.3	6.9	4.3	1.3
July	7.7	5.2	6.8	2.6	1.3	0.2	11.2	24.8	16.0	10.1	7.1	3.2
August	7.7	9.0	4.6	18.8	4.5	1.2	17.2	14.0	17.6	41.9	21.1	8.0
September	3.9	5.2	4.6	3.2	0.2	0.2	9.0	9.5	14.7	7.9	26.8	1.5
October	1.3	1.3	0.0	0.0	0.0	0.2	2.3	11.0	1.1	0.5	3.8	0.2
November	1.3	9.0	0.8	0.2	0.2	0.2	20.7	10.1	2.0	0.9	3.0	0.2
December	7.7	9.0	2.3	3.2	1.2	0.2	12.1	28.4	2.3	3.2	2.4	0.2
For year	1.3	1.3	0.0	0.0	0.0	0.2	37.3	23.2	18.2	9.8	9.4	5.7

See Water Supply and Irrigation Papers as follows:

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* Gaging station is located two miles below intake of water works, and these flows do not include that diverted for water-works purposes.

been a number of occasions when the flow at this point would have been insufficient to materially augment the water supply. In fact, the records of the years 1904 and 1910 clearly indicate that additional storage was absolutely necessary in order to secure a permanent water supply.

Water Consumption.

No facilities exist for accurately determining the amount of water consumed, as the supply is wholly by gravity without meters on the main supply lines. From such records as have been obtained from time to time of the flow in the open canal, it is believed that the maximum rate of consumption is considerably in excess of 2 000 000 gal. per day, and that the average daily consumption is in the neighborhood of 1 500 000 gal. per day. During the season when large volumes are used in " irrigating " the lawns and gardens, the daily consumption is probably about 1 750 000 gal.

Quality of Water.

Draining a rocky mountainous region, flowing through long and narrow gorges, with precipitous bluffs on either side, the Gallinas River naturally supplies very clear and pure water. In times of freshet, however, the water finds its way to the stream with such rapidity that large volumes of gravel, clay, and alluvium are carried in suspension. These freshet conditions are, however, confined in the main to one or two periods of time, of two to three weeks each, during the " rainy season."

Available Means of Safeguarding the Supply.

In order to improve the quality of the water supply, two practicable methods were considered, — filtration and storage.

FILTRATION.

Filtration offered some advantages over simple storage of water. Such a plant could be located within easier reach of the city,

might reduce the hazard of pollution, the suspended matter in the water at certain seasons, the possibility of taste and odor from algæ or other forms of growth, and might effect a saving in initial expenditure.

On the other hand, the filter plant had the disadvantage of not providing additional storage to supplement the minimum stream flow, a matter of increasing importance as the population and demand for water grows, and unfortunately involved far greater cost of operation and maintenance than did the project for a storage reservoir.

STORAGE.

Two sites for a storage reservoir were available in small lateral cañons tributary to the Gallinas River, one at a point abreast of Placita Llano, the other in a cañon or valley near the "Hot Springs," owned by the Cañon Lime Company.

Although the first location offered a good dam site, the comparatively steep slope of the cañon prevented the development of ample storage except at great expense.

The valley belonging to the Cañon Lime Company was admirably suited for a reservoir. Its mouth, a cañon through a quartzite ridge, running in a generally northerly and southerly direction, formed a natural site for a dam. The slope of the bed of the valley was sufficiently flat so that the basin formed by the dam was well adapted to a storage reservoir, and of much importance was the fact that this valley had no stream running through it except that created during the rainy season, by the rain falling within a very small watershed.

The drainage area was small, only 3.0 sq. miles. Therefore the run-off from it was practically insignificant, thus making it possible to collect and divert the storm flows upon it in a channel built around the edge of a reservoir, discharging them below the site of the dam and preventing the fouling of the clear water stored in the reservoir. This reservoir could be filled by means of a small canal or ditch, having an approximate capacity of 10.0 cu. ft. per sec., which would carry the water diverted during periods when the waters are clear, thus making available at all times a clear water as well as affording ample storage capacity.

Storage Reservoir Adopted.

In view of these advantages, the storage reservoir was adopted in preference to the filtration plant, and the dam was built at the mouth of the Cañon Lime Company's cañon.

Design of Dam.

In designing the dam, three types were considered, — a straight gravity section; the hollow reinforced dam of the Ambursen type; and the arched masonry type.

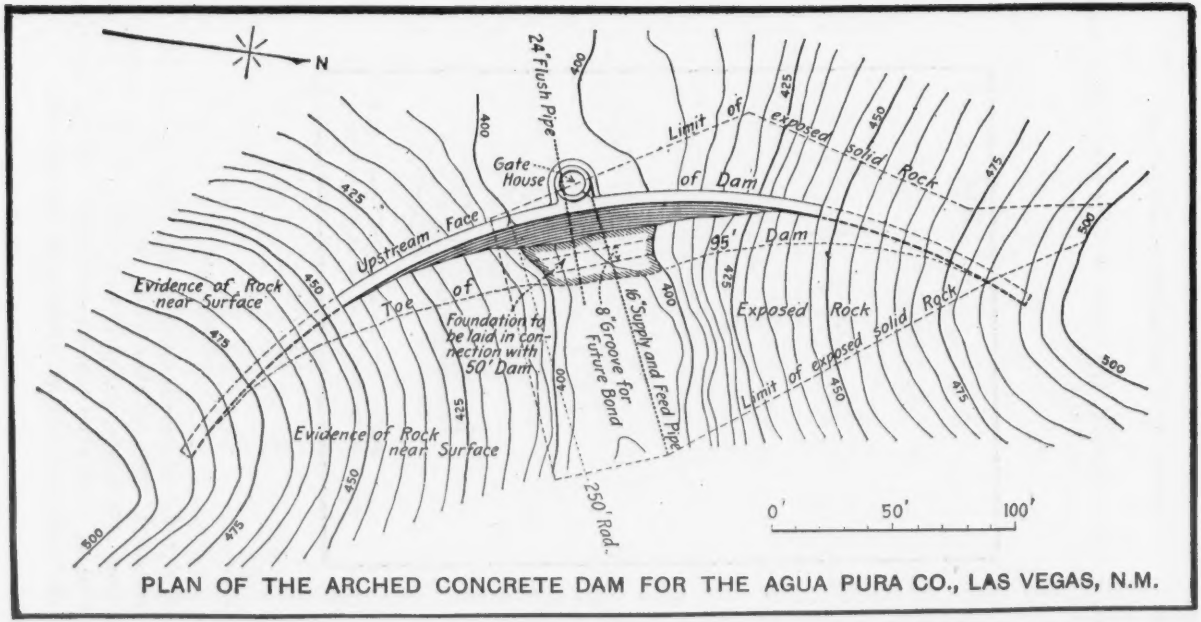
The outcrop of ledge on either side of the cañon, at the site selected for the dam, indicated that a very firm and solid foundation could be secured, as proved to be the case.

As a storage capacity of 60 000 000 gal. would serve the immediate needs of the water company and would probably be sufficient for a number of years to come, whereas ultimately a much larger storage would be required, it was desirable to decide upon a type of dam which could be built to such a height as to give this storage at the present time, with the provision that at some future time, the height of the dam could be increased sufficiently to give the additional amount of storage then required. A 50-ft. dam was sufficient to afford 68 000 000 gal. storage, while the site is such as to allow the construction of a dam 95 ft. in height, which would retain some 425 000 000 gal.

In order to provide for the ultimate increase in the height of the dam, it would have been necessary, had the Ambursen type been selected, to build the entire low level dam on the lines of the high level structure, whereas it was possible to design a solid concrete arched structure on lines suitable for the lower dam with the provision that ultimately this dam could be incorporated into and made part of a higher structure without increased present expenditure. Accordingly it was decided to construct a solid unreinforced concrete arched dam with a radius of 250 ft. and 50 ft. above the bed of the stream. See Figs. 14 and 15.

A comparison of the section of this dam with the sections of other similar structures appears in Table 5.

For further details upon the design of this structure reference



PLAN OF THE ARCHED CONCRETE DAM FOR THE AGUA PURA CO., LAS VEGAS, N.M.

FIG. 14.

can be had to a paper by Charles W. Sherman, in *Engineering News* of October 27, 1910.

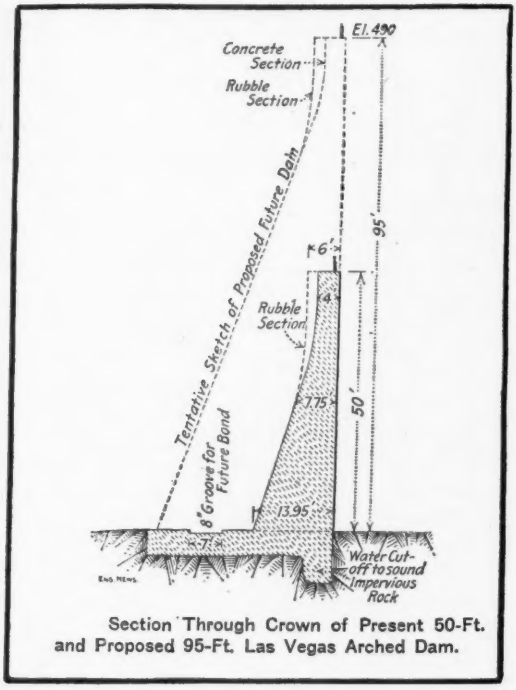


FIG. 15.

CONSTRUCTION.

Contract for the construction of the dam was awarded on September 21, 1910, to Mauretz M. Sundt, a local contractor, carpenter, and builder, equipped with a plant sufficient for this undertaking, though his experience had been confined largely to the construction of buildings, foundations, and sidewalks.

TABLE 5.

Principal Details of Curved Masonry Dams.

Place.	Max. Ht. Ft.	Thickness Base.	Thickness Top.	Max. Stress in Arch. Lb. per Sq. In.	Rad. Upstream Face.	Length Top.	Character of Rock.	Date.
(1) Katoomba, New South Wales	25	20.29	3.0	233	220	320	Sandstone	1905
(1) Picton, New South Wales	28	13.62	7.0	186	120	112	Sandstone	1897
(3) Winchester, Ky.	31	8.58*	4.83	498	318.4	407		
(1) Queen Charlotte Vale, New South Wales	32	8.65	3.0	155	90	113	Quartzite	1898
(1) Parkes, New South Wales	33.5	13.5	3.0	373	300	540	Granite	1897
(1) Lithgow No. 1, New South Wales	35	10.88	3.5	155	100	178	Sandstone	1896
(1) Wollongong, New South Wales	42	11.62	3.5	311	200	535	Basalt	
(1) Cootamundra, New South Wales	46	13.0	3.0	389	250	640	Granite	1898
(1) Wellington, New South Wales	48	10.0	3.0	311	150	350	Conglomerate	1899
(2) Bear Valley, Cal.	48 (Total 64)	8.4 at 48 ft.	3.17	825	335	300	Granite	
(1) Mudgee, New South Wales	50	18.0	3.0	311	253	498	Altered slate	1899
(1) Parramatta, New South Wales	52	15.0	4.8	223	160	225	Sandstone	
(3) Lewiston, Ida.	55.5	14.5	5.33	475	286.5	288		
(1) Tamworth, New South Wales	61	21.5	3.0	311	250	440	Granite	1898
(1) Medlow, New South Wales	65	8.96	3.5	186	60	124	Sandstone	1906
(1) Lithgow No. 2, New South Wales	87	24.0	3.0	155	100	221	Sandstone	1906
(2) Sweetwater, Cal.	90	46	12	188	222	380		
(4) Ithaca, N. Y.	90	7.75		283	67.85		Shale	1903
(2) Barossa, South Australia	95	34	4.5	242	200			1903
(2) Zola, France	119.7	41.82	19.02	196	158	205		
(4) Cheesman, Colo.	210 to 176 H. W.	72.66 at el. 100	18		399.89 at top		Granite	1900
(5) Pathfinder, Wyo.	210	94	10	181	(150 at center) (186.5 at base)			
Las Vegas (under contract)	50	15.50	5.0	350	250	210		1910
(proposed)	95	43.30	5.0	300	250	390	Sandstone	
(6) Cascadilla Creek dam, Ithaca, N. Y.	25	40	2.5	189	70	96	Shale	1904
(7) Upper Otay, Cal.	75	14	4	604	359	350		1900
(8) Crowley Creek, Malheur Co., Ore.	60	5.2	3.0	350	70	170		1898

(1) *Eng. News*, May 19, 1910.
(2) Wegman's "Dams," 5th edition.
(3) Data obtained from Wm. Wheeler, engineer.
(4) Trans. Am. Soc. C. E., Vol. 53.
(5) Jour. N. E. W. W. Association, June, 1906.
(6) *Eng. News*, November 10, 1910.
(7) Schuyler's "Reservoirs," 2d edition.
(8) *Eng. News*, August 24, 1911, p. 220.
* 15 ft. above base.

LABOR.

The labor employed upon the work was almost entirely Mexican, drawn from the immediate neighborhood, and was paid at the rate of $1.50 per day of ten hours.

EXCAVATION.

Work was begun, September 28, 1910, by stripping the earth from practically the entire site of the dam. The earth was thrown out upon the downstream side of the excavation, and the rock on the upstream side and rolled down the hill to the valley, where it was picked up and hauled to the crusher. About one fourth of the entire excavation (or, more particularly, 245 cu. yd.) was classified as earth excavation and was paid for at the contract price of 80 cents per cu. yd.

The rock excavation consisted of a fine, close-grained quartzite, lying below the surface at depths varying from a few inches to 6 ft., as shown in the accompanying photograph, Plate XVI, which also shows the ledge inclined or dipping to the west, or toward the reservoir, with an inclination of about 60 degrees with the horizontal.

In order to avoid the excavation of the ledge below the dam within the bed of the stream when it may prove desirable to raise the dam to a higher level, the ledge found in the river bed was excavated to an average depth of 6 ft. for the entire width necessary for the ultimate 95-ft. dam, said excavation being carried well into the side walls of the cañon and filled with concrete as shown in Plate XVI.

CONCRETE.

The concrete plant consisted of a Chicago Improved Cube Mixer, of ½-cu. yd. capacity. The stone was crushed at the site of the work by means of a small portable crusher.

ARRANGEMENT OF PLANT.

At the beginning of the work, in order to utilize the rock which was excavated from the site of the dam, the crusher was located about 100 ft. west of the face of the dam, within the reservoir site,

EXCAVATION FOR FOUNDATIONS AT SOUTHEASTERLY END OF DAM.

while the mixer was placed between the crusher and the site of the dam, the crushed stone being piled in close proximity to the mixer.

This location proved to be extremely convenient for the first three weeks, or until a height was reached that made the incline of the runway too steep for the wheelbarrows.

CRUSHED STONE.

In order to provide sufficient stone for the crusher, a quarry was selected within the reservoir basin, on the south side of the cañon and about 100 ft. westerly of the site of the dam. When the stone from the excavation was exhausted, the crusher was moved back, and the rock, as excavated from the quarry, was rolled down the hill, broken by means of large hammers, and fed to the crusher in its new location. At the same time (December 6) the mixing plant was also moved further from the dam, this position being adopted in order to make possible the erection of a runway for the wheelbarrows which would be sufficiently flat to permit of easy wheeling, even after the dam was well advanced.

By December 30, after three weeks' service in the second location, the runway again became too steep, and it became necessary to select a third location for the mixing plant.

As the quarry selected had developed a very inferior grade of stone, and as good material was difficult of access, the contractor decided, at the engineer's suggestion, to locate his plant on the opposite side of the valley, on top of the hill in line with the dam and near the newly constructed roadway over which it was necessary for all the sand to be carted.

By adopting this location, it was possible to save the expense of wheeling partly filled wheelbarrows of concrete up a long and tedious incline, and the operations of crushing and mixing were reduced to a minimum of labor and of effort. The expense of hauling the sand completely over the hill and down into the valley was also partly eliminated, as the teams could, in this new location, dump their load on top of the hill, thus making nearly twice as many trips as was possible in the second location.

Accordingly, the plant was moved during the first week in January to its third position, on the top of the hill, as shown in

Plate XVII. A terrace was constructed on the side of the hill, on which the mixing platform was built, of such a size and at such an elevation below the level of the roadway in which the crusher was placed as to provide ample storage for fully a day's supply of crushed stone. The mixer was located at a lower level so that the mixing platform was level with the top of the feeding hopper. The quarry was established on the top of the hill, where there was found an ample supply of very satisfactory stone. As the stone thus quarried was within easy reach of the crusher, the handling of materials was reduced to a minimum from the time the stone was quarried until it was dumped from the mixer directly into a long chute which led directly from the mixer to a distributing box just above the wheeling platform constructed on the top of the forms.

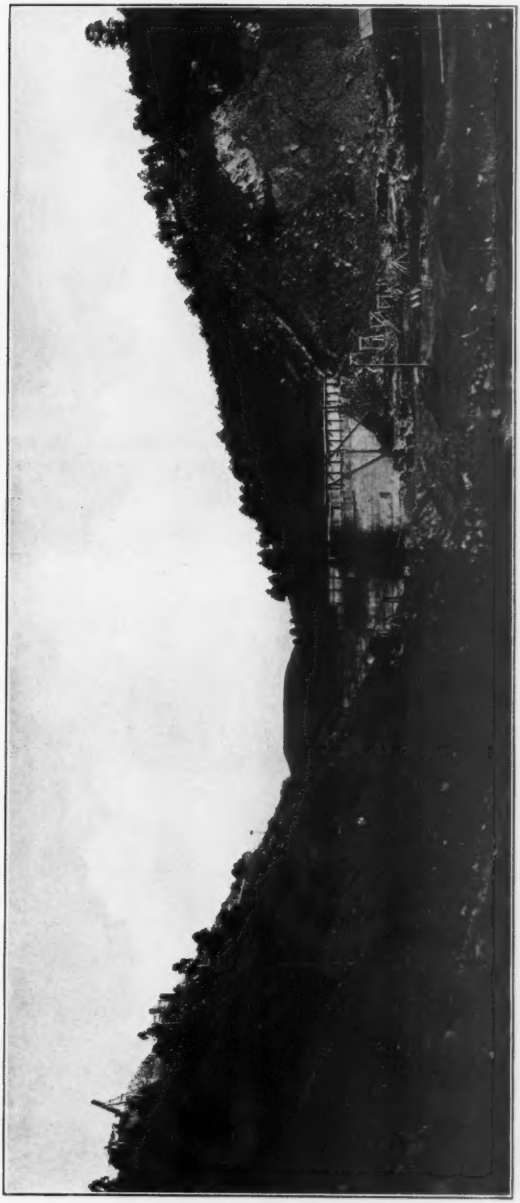
The loading of concrete into wheelbarrows was controlled by a shear gate in this distributing box by means of which each batch of concrete was disposed of as rapidly as it was mixed, while separate runways for the loaded and empty wheelbarrows made it possible to distribute the concrete with a minimum of labor.

By this arrangement about twice as much concrete was mixed and placed per day as the same force of men had been able to do during the latter part of the time when the mixing plant was in its second position.

RELATIVE OUTPUT DURING DIFFERENT PERIODS.

In order to determine the relative amounts of labor employed in the several subdivisions of the work during each of the three periods of construction, a mass diagram has been prepared, as shown in Fig. 16. The three periods above referred to are determined by the location of the plant, namely, first period, with mixing machinery near the site of the dam; second, with machinery, including the crusher, in the valley at some distance from the dam, and third, with entire outfit on top of the hill in line with the dam.

The mass diagram was constructed with accumulated volumes of concrete in cubic yards, as abscissæ, and the accumulated amount of labor expended, as ordinates. The records of labor



VIEW OF PARTLY COMPLETED DAM FROM RESERVOIR SITE.

employed in the following subdivisions of the work, namely, quarrying, crushing stone, concrete mixing and placing, and stagings and forms, have been plotted in terms of the corresponding amounts of concrete placed. These points have been connected, forming an irregular line, while the average condition for each

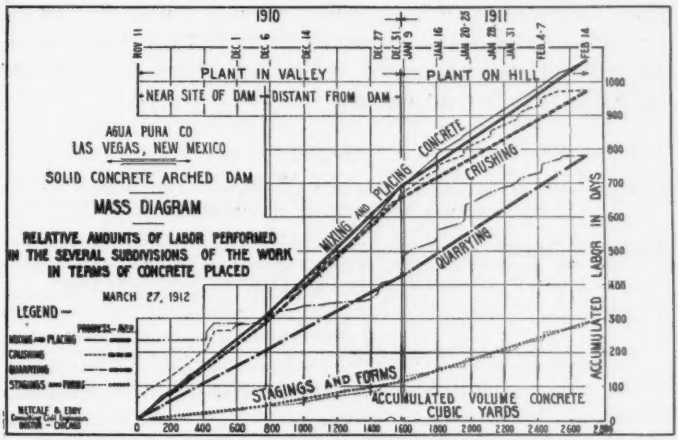


FIG. 16.

period, for each subdivision of work, has been shown by a straight line of heavy weight. These data are expressed in tabular form, Table 6.

QUARRYING.

The quarry was well advanced when concreting began, 230 days of labor having been performed, while all of the stone quarried was consumed by December 31, at which time 1 582 cu. yd. of concrete had been placed, with a total expenditure of 424 days of labor in quarrying. The amount of concrete laid per laborer employed in the quarry is indicated by the slope of the line drawn from the origin to the point whose coördinates are 1 582; 424. In other words, 3.73 cu. yd. of concrete were laid during this period per day's labor employed in the quarry. Similarly, we find that

3.14 cu. yd. of concrete were laid after January 1 for each day of labor employed in the new quarry upon the top of the hill.

STONE CRUSHING.

In the same manner we find that during the first period of construction 2.60 cu. yd. of concrete were laid for each day of labor employed in crushing stone, whereas during the second period only 2.28 cu. yd. of concrete were laid per day of labor, while during the third period, 3.5 cu. yd. of concrete were laid per day of labor in crushing stone.

TABLE 6.

CONSTRUCTION OF ARCHED CONCRETE DAM FOR THE AGUA PURA COMPANY AT LAS VEGAS, N. M. 1910–1911.

Yardage of Concrete placed per Laborer-day expended in the Several Subdivisions of the Work during the Three Periods of Construction, determined by the Relative Positions of the Mixing and Crushing Plants to the Dam.

Subdivision of Work.	First Period.	Second Period.	Third Period.
	Machines in the Valley.		Machines on Top of Hill in Line with Dam.
	Near Dam.	150′ from Dam.	
Quarry	3.73		3.14
Crusher	2.60	2.28	3.50
Concrete mixing and placing	2.52	2.10	3.02
Stagings and forms	20.8	11.0	6.33

CONCRETE MIXING AND PLACING.

Similarly, during the first period 2.52 cu. yd. of concrete were laid for each day of labor employed in mixing and placing, while during the second period only 2.10 cu. yd. were laid, and during the third period 3.02 cu. yd. were laid per day of labor employed in mixing and placing.

STAGINGS AND FORMS.

In connection with the construction of stagings and forms, we find that for each day's labor employed during the first period 20.8 cu. yd. were laid, while during the second period but 11.0

cu. yd. were laid, and that during the third period, only 6.33 cu. yd. were laid for each day of labor employed in building stagings and forms.

QUARRY. — RATE OF PROGRESS.

That the quarrying cost more during the third period than during the first two periods is undoubtedly due to the fact that the carpenters were unable to provide forms during the third period sufficient to furnish the mixing and placing crew with a full day's employment. Consequently, almost every day the labor from this crew were turned into the quarry, which resulted in disorganizing the regular quarry crew, so that the increase in output was not proportionate to the increase in labor employed. Had it not been for this disorganizing effect, or had good foremanship been maintained in the quarry, it is probable that the quarrying during the third period would have been at about the same rate as during the first two periods, or possibly slightly better.

CRUSHED STONE. — RATE OF PROGRESS.

That more yardage were placed per laborer employed in crushing during the first period than during the second, is due to the use of the rock found in the excavation for the dam, which was readily delivered to the crusher. The position of the crushed stone platform in the third period, some ten feet lower than the base of the crushing plant, thus avoiding the congestion of the crushed stone around the crusher, together with the fact that the stone was utilized about as fast as it was crushed, as well as the fact that the raw material was piled conveniently close to the crusher, is sufficient reason to explain the great difference in results during the third period.

CONCRETE. — RATE OF PROGRESS.

The slopes of the lines on the diagram, Fig. 16, representing the mixing and placing of concrete, vary in the different periods about as might be expected, except that during the first period, with the machinery placed at the edge of the excavation and some distance above the bottom thereof, the concrete should have been made and placed under such conditions with far less labor than would be

required after the machinery was moved some 150 ft. from the edge of the excavation in a position which required not only longer wheeling circuits but during most of the time the wheeling of loaded wheelbarrows upgrade, whereas in the first position the bulk of the loads were wheeled downgrade and upon very short circuits.

It is probable that the difference is due to the fact that during this first period a great deal of time was lost on account of leaking flues in the old boiler which supplied the steam for the concrete mixer, thus resulting in the entire crew remaining idle while the engineer cleaned, or rolled, his flues. It is estimated that had the new boiler, which was used during the second period, been made use of from the beginning of the work, the concrete might have been placed during the first period at the rate of 3.5 yd. per day of labor employed.

Although the curve showing the actual conditions during the second period as plotted is not far different from the straight lines showing the average conditions, it is to be noticed that the slope of the line showing actual conditions at the end of the second period is much steeper than the average, and it is believed that had the work continued for another week with the machinery in the second position, the slope would have represented the placing of not more than one yard of concrete per day of labor employed, whereas by moving to the top of the hill it was possible to mix at the rate of three yards per day of labor employed.

The reasons for this improvement have already been alluded to, and may be enumerated as follows: First, the relation of the operating platform, mixer, chutes, and wheeling platform were such as to enable each set of men to perform their respective tasks without interference, and with a minimum of labor. Second, with the operating platform located above the mixing hopper the engine was no longer called upon to raise the "feeding pan" in order to charge the mixer, thus saving both time and steam, as the hopper, which was loaded while the previous batch was being mixed, could be discharged directly into the mixer immediately following the dumping of the previous mix. Third, the wheelbarrow crew could remove and place the concrete as fast as it was mixed, and there was always an ample supply of crushed stone

and sand in close proximity to the mixing hopper, and the water was rapidly supplied through a large valve from a barrel supported over the mixer, so that the whole operation was one that created interest among the workers to the extent that each appeared to desire to have his part of the process ready without causing delay to the operation.

The average output during this third period was at the rate of 36 one-bag, or 0.2 cu. yd., batches per hour, while the maximum day's output was at the rate of 47 batches per hour, which rate was continued for seven hours, and the minimum rate was 26 batches per hour.

FORMS.

It is to be noticed that although there was practically no carpenter work during the first half of the first period, except for the construction of runways, there was nearly as much labor employed per yard of concrete during the first part of this period as was employed during the later portion. This is due in great measure to the same cause as has already been referred to in connection with the making of concrete, namely, an insufficient and worn-out boiler gave the crew frequent opportunities to remain idle.

That more labor was required during the third period than during the second is due to the fact that all of the concrete was delivered to the wheeling crew at the bottom of the incline chute at the north end of the dam, and as the wheeling platforms were supported upon the top of the forms it was impossible to construct new forms at the north end of the dam while the concrete was being delivered to the dam. Accordingly, the concrete mixing was stopped for a day while the carpenters erected the forms at the north end of the dam. While this section was being filled the carpenters then prepared the adjoining section of forms, and while this was being filled they erected the third set of forms, and similarly with the fourth section, so that the fifth day the mixing crew was laid off and the carpenters rushed upon the erection of the northerly set of forms for the next zone, erecting this in one day, in order not to delay the mixing more than one day.

The result was that a large number of inexperienced men were assigned to assist the carpenter in the construction of these forms,

and especially so on the day while the mixer was shut down, as shown by the vertical lines in the diagram which gives a " saw-tooth " effect to the line representing the actual conditions. It is to be noted that were it not for the influx of labor on these special days the " saw-tooth " effect would have been less marked and the slope of this line would have been substantially parallel to the slope of the average line during the second period, thus indicating that the excess cost of stagings and forms during the third period was due in great measure to the superabundance of labor on the days mentioned.

Unit Costs.

Daily cost accounts were kept by the engineer, under the headings of " Excavation " and " Concrete," the latter being subdivided as follows: Quarry, Crushed Stone, Sand, Cement, Mixing, Heating, Wheeling, Placing, Placing Cyclopean Masonry, Water Supply, and Stagings and Forms.

For each of the foregoing subdivisions, separate records were kept under the following headings: " Labor and Teams," " Superintendent, Foreman, and Blacksmith," " Materials and Supplies," and " Tools, Equipment, and Repairs."

In order to make the records as complete and accurate as possible, arrangements were made with the contractor whereby he gave the engineer access to his time-book and furnished monthly statements of amounts and costs of materials furnished and of expense involved in repairs, etc., the items of which were distributed according to the engineer's discretion.

It is believed that the tabulated costs submitted herewith in Tables 7 and 8 represent very closely the actual unit costs upon this work. In Table 9, a summarized statement of costs has been prepared, showing the relation of " cost to the contractor " to the " cost to the Agua Pura Company," indicating the probable profit and loss under the items of earth and rock excavation, concrete, and under the item of extra work. As will be noted from the memorandum attached to this table, these figures include $1 224 extra compensation paid to the contractor for prosecuting the work through the cold weather instead of closing down as the contract permitted him to do.

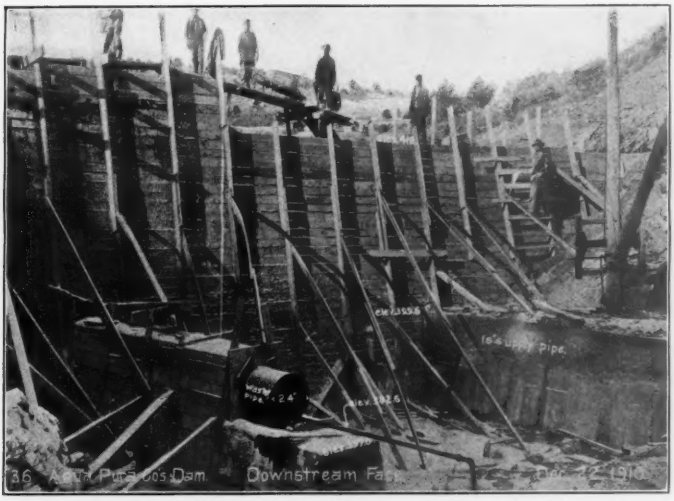


FIG. 1.
DAM UNDER CONSTRUCTION — DOWNSTREAM FACE.

FIG. 2.
UPSTREAM FACE OF DAM DURING CONSTRUCTION.

TABLE 7.

Agua Pura Company's Dam.

ESTIMATED COST TO CONTRACTOR, FROM BEGINNING TO DECEMBER 31, 1910. (PLANT IN VALLEY.)

Concrete (1 582 cu. yd.).

Item.	Labor and Teams.		Supt., Foreman, and Blacksmith.		Materials and Supplies.		Tools, Equip., and Repairs.		Total Cost.	
	Total. $	Unit $	Total. $	Unit $	Total. $	Unit $	Total. $	Unit $	Total. $	Unit $
Quarry										
Drilling..	167.85	0.10								
Labor ...	394.78	0.25								
Total..	562.63	0.35	89.57	.06	77.88	.05	13.86	.01	743.94	0.47
Crushing										
Setting up	39.25	.02								
Engineer.	198.20	.13								
Labor and team...	847.65	.54								
Total..	1 085.10	.69	103.20	.07	120.95	.07	439.24	.28	1 699.19	1.11
Sand										
Teams...	306.40	.19								
Labor....	149.60	.10								
Total..	456.00	.29	42.60	.03	3.80		17.11	.01	519.51	0.33
Concrete										
Mixing...	36.00	.02								
Teaming coal ...	6.00									
Engineer.	123.45	.08								
Sand.....	101.20	.07								
Stone....	202.40	.13								
Cement..	50.60	.03								
Water & dump..	101.10	.07								
Total.	620.75	.40	56.60	.03	92.30	.06	366.72	.23	1 136.37	0.72
Heating Material.	82.35	.05	8.15		85.05	.06	3.00		178.55	0.11
Wheeling...	351.60	.22	35.10	.02			21.00	.02	407.70	0.26
Placing....	155.85	.10	15.65	.01	31.40	.02	12.60	.01	215.50	0.14
Placing Cyclop....	55.85	.04	5.60				50.50	.03	111.95	0.07
Stage and Forms										
Carpenter	106.50	.06								
Labor....	126.95	.08								
Team....	62.30	.04								
Total..	295.75	.18	22.10	.02	385.10	.24			702.95	0.44
Cement										
Cement shed...	79.80	.05								
Teams...	192.00	.12								
Total..	271.80	0.17	21.30	.02	5 113.00	3.24	82.50	.05	5 505.60	3.48
Total concrete....	3 937.68	2.49	399.87	.26	5 926.48	3.78	1 006.53	.64	11 270.56	7.13

TABLE 8.

Agua Pura Company's Dam.

ESTIMATED COST TO CONTRACTOR FOR MONTHS OF JANUARY AND FEBRUARY (TO MARCH 15, 1911). (PLANT ON HILL.)

Concrete (1 121 cu. yd.).

Item.	Labor and Teams.		Supt., Foreman, and Blacksmith.		Materials and Supplies.		Tools, Equip., and Repairs.		Total Cost.	
	Total. $	Unit $	Total. $	Unit $	Total. $	Unit $	Total. $	Unit $	Total. $	Unit $
Quarry										
Foreman.	56.00	0.05								
Labor....	497.55	.45								
Team....	36.80	.03								
Total..	590.35	0.53	84.41	.07	18.30	.02	11.20	.01	704.26	.63
Crushing										
Setting up	32.50	.03								
Engineer.	134.50	.12								
Labor....	408.70	.36								
Total..	575.70	.51	72.33	.07	60.40	.05	148.02	.14	856.45	.77
Sand										
Teams...	314.00	.28								
Labor....	128.85	.11								
Total..	442.85	.39	52.56	.05	31.25	.03	13.06	.01	539.72	.48
Cement										
Cement shed...							44.26			
Labor...	9.00	.01								
Teams...	77.20	.07					4.50			
Total..	86.20	.08	11.80	.01	3 711.53	3.31	48.76	.04	3 858.29	3.44
Concrete Mixing										
Setting up	38.75	.03								
Engineer.	75.50	.07								
Sand.....	37.30	.03								
Stone....	115.65	.11								
Cement..	38.80	.03								
Water and dump...	93.90	.09								
Total..	399.90	.36	49.72	.04	68.44	.06	199.62	.18	717.68	.64
Heating Material.	8.25	.01	1.14				6.00		15.39	.01
Wheeling...	148.35	.13	20.14	.02			14.00	.01	182.49	.16
Placing....	78.90	.07	10.65	.01			24.00	.02	113.55	.10
Water Supply.....	82.65	.07	11.42	.01			11.50	.01	105.57	.09
Stage and Forms										
Carpenter	164.75	.15								
Labor....	227.77	.20								
Total..	392.52	.35	53.28	.05	238.54	.21			684.34	.61
Cleaning up	220.55	.20	12.95	.01					233.50	.21
Total concrete	3 026.22	2.70	380.40	.34	4 128.46	3.68	476.16	.42	8 013.34	7.14

FOUNDATION OF DAM.

TABLE 9.

Concrete Masonry Dam Built for the Agua Pura Company, Las Vegas, N. M., 1910, 1911.

SUMMARIZED STATEMENT COMPARING COST TO THE CONTRACTOR WITH THE PRICE PAID BY THE WATER COMPANY.

Item.	Cubic Yards.	Cost to Contractor.		Cost to Agua Pura Co.		Contractors' Profit and Loss.			
		Total.	Unit.	Total.	Unit.	Profit.		Loss.	
						Total.	Unit.	Total.	Unit.
Earth excavation	245	$1 533.15	$1.50	$1 460.00	$1.43			$73.15	$0.07
Rock excavation	790								
Concrete in dam, gatehouse substructure and superstructure	2 720*	19 283.90	7.09	21 318.05†	7.86	$2 034.15	$0.77		
Premium on indemnity policy		246.86						246.86	
Extra work		225.98		259.88		33.90			
						$2 068.05		$320.01	
		$21 289.89		$23 037.93		$1 748.04			

* 17 cu. yd. has been added to yardage paid for in final estimate to include yardage contained in gatehouse superstructure.

† Includes $1 224.00 extra compensation paid for prosecuting work through cold weather.

Wages: Mexican labor, 15c.; sub-foreman, 17½c.; engineer, 25c.; carpenter, 30c. and 20c.; foreman, 35c.; double teams, 40c.

Materials: *Cement*, $3.02 f. o. b. Hot Springs; rebate on bags, 30c. — figured as 25c. to allow for loss.
Lumber (per M ft. b. m. at mill), $17.00; mill work, $0.60. Cull lumber, $10.00.
Stone, sandstone quarried and crushed at site of work.
Sand, river sand screened and hauled about one-half mile.
Coal, $3.00 per net ton (f. o. b. Hot Springs).

Contractor's Compensation. The above figures of "Cost to Contractors" include an allowance of $400 or $8.00 per day for fifty days' time spent by him at the site of the work.

The hourly rates of wages paid are as shown in the footnote, namely, — Mexican labor, 15¢; subforemen, 17½¢; engineer, 25¢; carpenter, 30¢ and 20¢; foreman, 35¢; and double teams, 40¢.

The average cost of materials was as follows: Cement, $3.02, f. o. b. Hot Springs, with rebate on bags amounting to 30¢, which has been figured in these costs at 25¢ to allow for loss, giving net cost of cement $2.77. Lumber, $17.00 per M ft. b. m.; cull lumber, $10.00 per M ft. b. m. at the mill. Mill work, 60¢ per M ft. Stone was quartzite quarried at the site of the work. Sand was secured from the river bed, screened and hauled about 0.5 mile. Coal, bituminous, $3.00 per net ton, f. o. b. Hot Springs.

In figuring the costs, an allowance was made for actual time spent by the contractor upon the work at the rate of $8.00 per day, and included fifty days' time, amounting to $400.

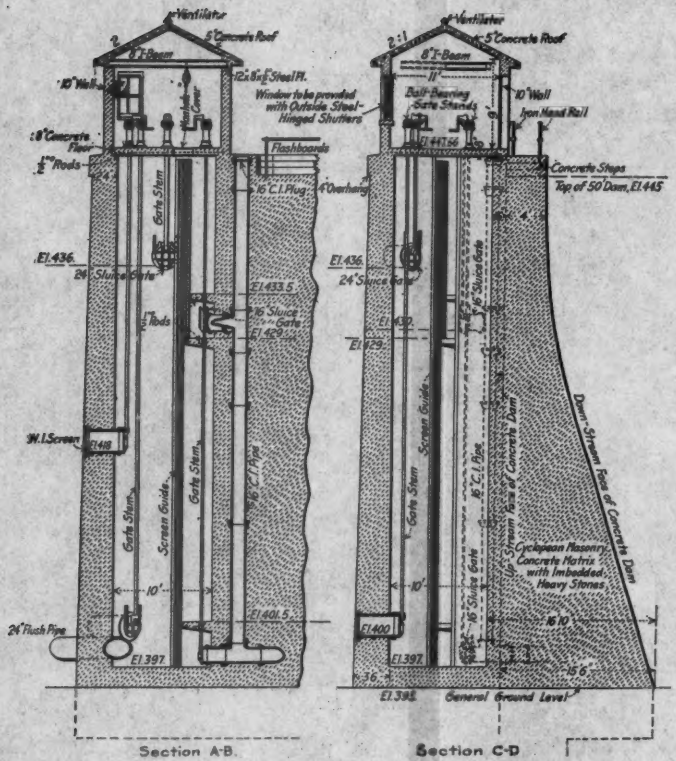
In Table 10 is given a statement of the charges included in the force account, which table indicates the first cost of the machinery, tools and materials, the amount charged to the work and its percentage of the first cost and the estimated value of the several items at the close of the work. From this table it will be seen that an allowance for tools and equipment, amounting to $1 066.20, has been included, which, compared to the first cost of the tools and equipment, amounting to $2 904.90, is equivalent to nearly 37 per cent. of the first cost.

Materials. — cement.

The cement used upon this work was the "El Toro" brand, manufactured by the Southwestern Portland Cement Company at El Paso, Tex., and proved to be a most satisfactory cement. Tests were made in accordance with the specifications of the American Society of Civil Engineers by the George Pierce Testing Laboratory at Portland, Colo., and the cement was purchased a sufficiently long time in advance to enable the securing of a 28-day test.

sand.

The sand was secured from the bed of the Gallinas River, passed through a ½-in. screen in order to remove occasional gravel, and hauled fully 0.5 mile up two long and steep hills.



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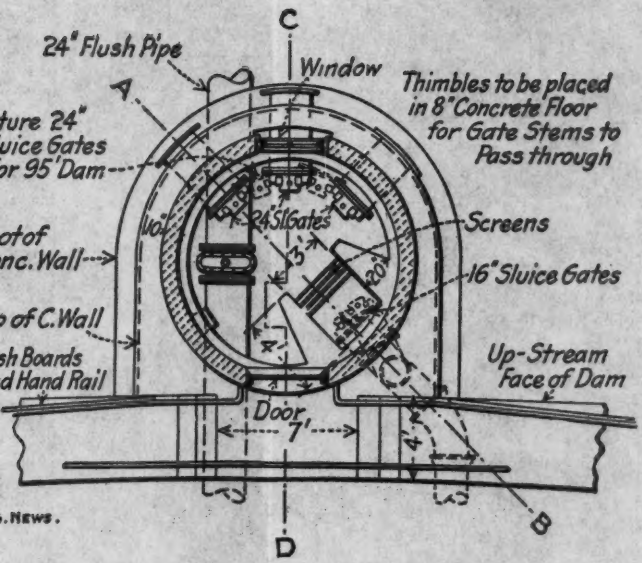


Plan of Concrete Gate Chamber,
(Floor Removed.)

PLAN AND SECTION THROUGH
ATE HOUSE OF LAS VEGAS ARCHED DAM.

CRUSHED STONE.

As already described, the stone was of good quality sandstone, and was crushed locally. In order to supply the stone in sufficient quantity to keep the mixing and placing crews busy throughout the day it was necessary to operate the crushing plant in two shifts of ten and twelve hours respectively.

TABLE 10.

STATEMENT OF CHARGES INCLUDED IN FORCE ACCOUNT.

Tools and Equipment.	First Cost.	Amount Charged.	Per Cent. Charged.	Value Remaining.
Cement mixer	$700.00	$350.00	50	$350.00
Stone crusher	1 350.00	337.50	25	1 012.50
Steam pump	57.50	11.50	20	46.00
Boiler	114.70	28.70	25	86.00
Boiler hoods	6.25	1.50	24	4.75
Derricks and ropes	201.08	100.50	50	100.58
Wheelbarrows and small tools	155.62	116.83	75	38.79
Blacksmith tools	30.96	10.06	33	20.90
Wagon — new	85.00	22.10	26	62.90
Sand screens	38.30	16.97	44	21.33
Torches	4.25	2.54	60	1.71
Flue roll and beader	4.00	.80	20	3.20
Steam and water hose	52.00	31.20	60	20.80
Pliers and wrenches	2.02	.60	30	1.42
Old smoke-stack	10.00	9.00	90	1.00
Pipe and fittings	26.97	10.80	40	16.17
Injector	6.75	2.70	40	4.05
Belting (not used)	21.50	1.50	7	20.00
Wagon sheets	38.00	11.40	30	26.60
Totals	$2 904.90	$1 066.20	36.7	$1 838.70
Cement Shed				
Material	145.06	95.06	65	50.00
Labor	25.20	25.20	100	
Repairs	417.23	367.23		50.00*
Totals	$3 492.39	$1 553.69		$1 938.70
Materials				
Cement remaining				120.00
Cement bags returned				785.00
Lumber — cull				50.00
				$2 893.70

* Rebate on pitman.

FORMS.

The forms were made of 2-in. by 8-in. planks, dressed on two edges and one face, and for the lower twenty feet of the structure were braced by means of 2-in. by 6-in. studdings, with numerous 2-in. by 4-in. braces, as shown in Plate XVIII, Fig. 1. For the balance of the structure the forms were made by the use of 3-in.

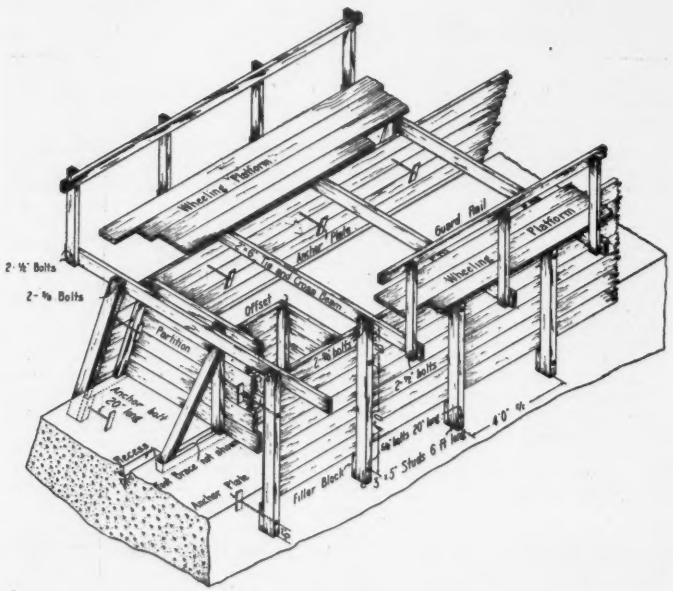


FIG. 17.
FORMS FOR CONCRETE DAM.

by 5-in. studs, 6 ft. long, with bolt holes placed 4 ft. apart 6 in. from lower end and 18 in. from upper end, so arranged that the $\frac{5}{8}$-in. bolts, 20 in. long, previously set in the wet concrete 12 in. below the surface of the concrete and projecting 8 in. from the face of the dam, would pass through the lower hole of these studdings, which would then be bolted up against a 2-in. wooden

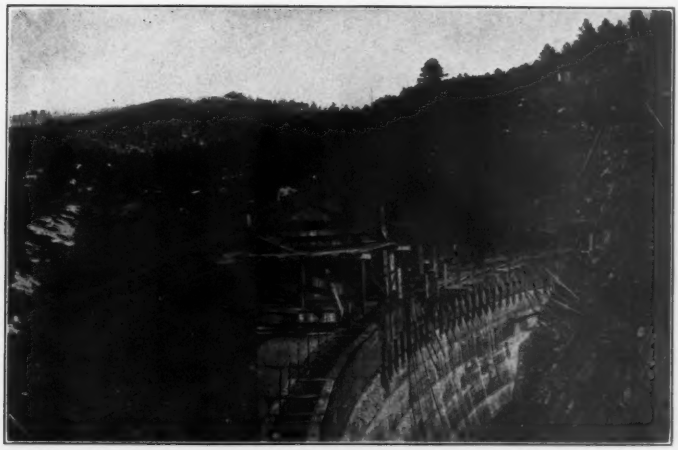


FIG. 1.
TOP OF COMPLETED DAM BEFORE REMOVAL OF FORMS.

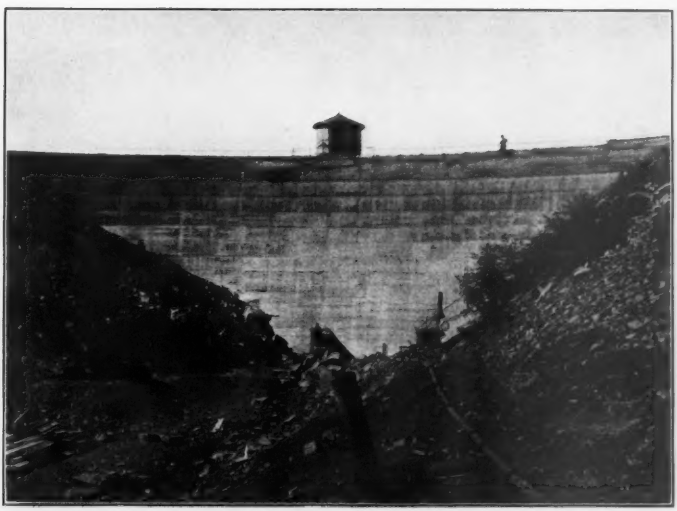


FIG. 2.
DOWNSTREAM FACE OF COMPLETED DAM.

washer which separated the studding from the face of the concrete by the thickness of the forms.

As these studdings were arranged in pairs on either face of the dam on radial lines, it was possible to hold the forms rigidly in place by means of tie-braces across the top, which braces also served to carry the wheeling platforms across the top of the dam, as shown in Plate XVIII, Fig. 2, and Fig. 17. Each time a new block of concrete was placed, new bolts were inserted in the upper holes bored through these studdings, which in turn served as anchorages for the next tier of concrete.

No difficulty was experienced in keeping the forms in line except when the last layer of concrete was placed; in order to bring the dam to the finished crest in one zone, rather than to permit two thin zones to be constructed at the top of the dam where the pressure of ice action must be guarded against, it became necessary to splice these studdings.

HEATING MATERIALS.

As the thermometer in these cañons, during the winter months, frequently drops below freezing during the night and early morning, and sometimes even considerably below zero, whereas during the middle of the day the thermometer is almost always above freezing and frequently remains in the vicinity of 55 degrees and 60 degrees for a greater portion of the day, it was deemed advisable to be prepared to heat the sand and water so that the concrete might be thoroughly warmed when placed. Accordingly, a number of large condemned iron smoke stacks were procured, in which cord wood could be burned while the sand was piled over and around them, by which means it was possible to secure thorough and complete heating. The water was warmed by means of a steam jet constantly blowing into the water tank, and the concrete was covered with canvas, straw, and boards during the night.

We were, however, fortunate enough to experience but little weather in which the temperature was so low as to require the heating of the sand, except on four or five occasions, although it is true there were two periods of several days' duration when the

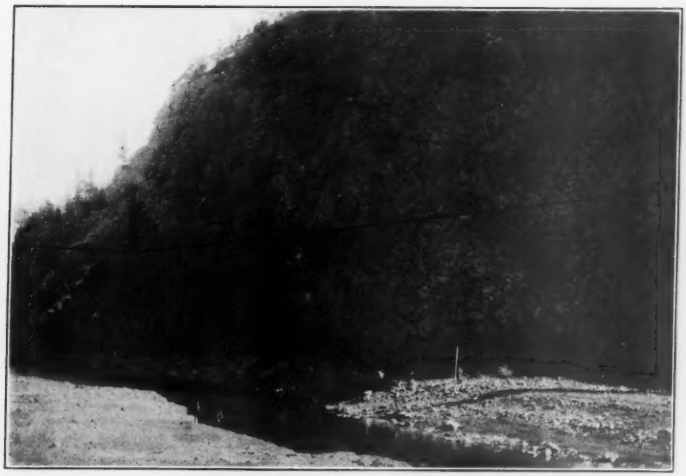
thermometer went as low as 10 degrees to 20 degrees below zero, but on each of these occasions the work was shut down at the time on account of mechanical defects in the machinery or for other causes.

Cyclopean Masonry.

When the work was contracted it was expected that the Cyclopean form of masonry would be adopted, and with this in view, the contractor erected two small guy derricks, hand operated, which proved to be entirely inadequate for handling the large stones profitably and satisfactorily, with the result that probably not over 200 cu. yd. of stone were thus utilized, and this only in the lower portion of the structure. It is probable that not over 20 per cent. of the first thousand yards of concrete was composed of large stones, or not over 8 per cent. of the entire structure.

When the cyclopean method was used, the stones were placed to break joints horizontally and projecting above the top of the concrete at the end of the day's work, so as to form dentals by which the next course of concrete would be bonded thereto, as shown in Plate XIX. After the cyclopean form was discontinued, the bonding in the horizontal surfaces was secured by imbedding 4-in. by 4-in. timbers, beveled $\frac{1}{2}$ in. on each of the two opposite surfaces, placed lengthwise of the dam in the middle of the surface, which were removed when the surface was cleaned preparatory to the construction of the next course. The vertical joints within a given course were made by means of a three-faced bulkhead, thus securing an offset of about 2 ft. about midway of this joint.

Before the concrete was placed in the excavation the surfaces of all ledge were thoroughly cleaned of earth, dust, and vegetable matter by means of a stream of water from a hose under pressure, or else by means of steam under high pressure, together with stiff brooms and shovels. In a similar way the surfaces of concrete were cleaned before the succeeding layer of concrete was placed, thus insuring not only the removal of dust, dirt, and chips, but also securing the thawing of any ice which occasionally was found on the surface of the concrete in early morning.



CLIFFS ALONG GALLINAS RIVER, AND LINE OF PROPOSED FLUME.

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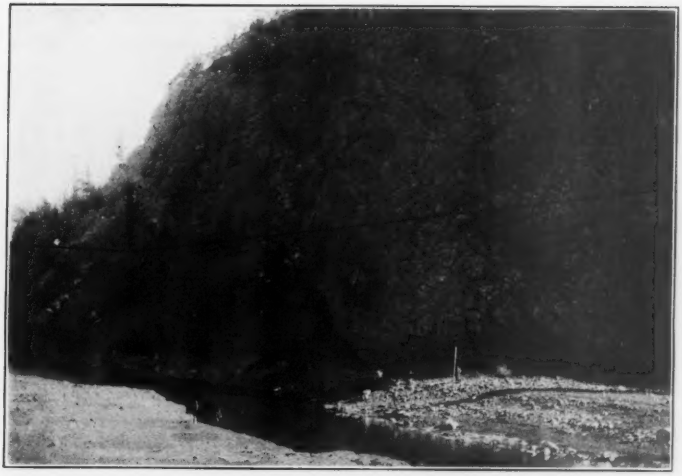

CLIFFS ALONG GALLINAS RIVER, AND LINE OF PROPOSED FLUME.

Gate Chamber.

The gate chamber was built on the upstream face of the dam, and contained two gates at different levels on supply main, and three gates leading into the reservoir at different levels so as to provide for circulation in the waters of the reservoir. These gates, together with a blow-off gate, were operated from the gate-house floor by means of bevel-geared gate-stands anchored thereto. Provision was also made within the gate-house for two sets of screens for each of the inlet gates, although at the present time but one screen was placed for each gate. The openings for the 24-in. gates leading into the reservoir were protected by means of gratings so as to prevent floating material from flowing into the gate-chamber. See Plate XX.

Completion of the Dam.

With the exception of the construction of the gate-house, the dam was completed February 14, 1911. It contains 2 703 cu. yd. of concrete. The excavation for foundations amounted to 790 cu. yd. of rock and 245 cu. yd. of earth. See Plate XXI.

Gate-House.

The superstructure of the gate-house was built with a small crew of men in three days after the forms were erected. The construction of these forms required the services of one carpenter and five men for a period of three days. The construction of this gate-house was, however, delayed until the early part of the month of March on account of a very severe blizzard during the latter part of February.

Feeder Canal.

Plate XXII indicates some of the difficulties to be encountered in the construction of a high-level canal by which the water is to be delivered to this reservoir from the Gallinas River. The line across the face of the photograph indicates the approximate location of the canal. There are a number of such cliffs along the line selected for the canal, and at each a box flume will be constructed and supported on wrought iron brackets on the face

of the cliff. The flume will be built out gradually from bracket to bracket, the holes for each bracket being drilled from a stage supported as a cantilever from the two brackets next preceding. This affords an inexpensive construction and although it may become damaged from time to time by falling rocks from the overhanging cliffs, it is anticipated that repairs can be easily made.

PAINT FOR STANDPIPES, AND METHODS OF APPLYING.

TOPICAL DISCUSSION.

(November 13, December 11, 1913.)

MR. GEORGE A. STACY.* Mr. President, this is one of the little things pertaining to water works that we are hunting for information on. We depend entirely upon hydrant service, as we have no steamers, so we erected a standpipe, with an independent line of mains and hydrants, for the higher level of the city. As this standpipe is used for fire service only we did not have to be so particular in regard to the paint which was put on the inside, as to its communicating taste or odor to the water. The standpipe was built in 1895, and the specifications called for two coats of the best asphaltum paint that we could hear of at that time. I thought as I looked at it, after it was on, that it would be almost as permanent as enamel and would be a thorough protection to the wrought iron.

In about three years I noticed that it looked as though the paint was all gone. We drew the water off, and even with the microscope you could not detect that there had ever been any paint on the tank in any way, shape or manner, not even in the joints or around the rivets, or anywhere else. I do not know how long the tank had been in that condition, for I had such confidence in the paint that I had never thoroughly examined it. The water was not used for our domestic supply so the fluctuation of water level in the tank was very slight, five feet was the maximum in the winter, when we keep it from freezing by artificial circulation, and one or two feet in the summer.

In repainting we got some paint which was highly recommended,

*Superintendent Water Works, Marlboro, Mass.

some discovery which they claimed made this paint particularly adapted for this kind of work. We had looked around but couldn't find any reliable data which we could go by as to paint that anybody else had used, so we put that on. This did a little better, but at the end of three years was gone. Then we tried something else which had been recently discovered and which had come into use to a certain extent at that time for coating steel pipe. We put that on, and I watched it as time went along, and we found that near the water line, or the ice line, where the ice broke as the water rose and fell in the tank, the ice would break away from the side, and it seemed to affect the paint there more than anywhere else; at the end of three years we emptied the tank to see its condition. We found the paint which was purported to be very elastic and very tough hanging on the sides of the tank in places like loose paper on the wall. There would be a strip attached to the top and hanging loose, and then some few feet off another, and some of it you could pull off. It certainly was tough, but it did not adhere to the iron, so that it was no protection to what was behind it.

I thought, perhaps, that that was due to some imperfection in preparing the tank. I thought the matter over, but I did not see how we could do any better than we had, because the iron was perfectly clean, and there was no question about its being dry, because it was so hot in there when the sun shone that it was very uncomfortable, and when the water was drawn out it didn't take but a little time for the tank to dry, so I laid it to the paint.

This carries us along quite a period, and then we tried a paint which was made of different material. We put that on a few years ago, — I guess it has been painted once since, — and that stayed on about three years and a half or four years, and when we drew the tank off to paint it again it was in the best condition that it ever had been. The paint on the bottom was almost perfect. I thought then we had found what we were seeking, that is, something which had durability and which would last three years and remain effective. So I got the same paint, as I supposed, and applied it again; and in three or four years we drew the tank down and this time it looked a good deal as it did the first time we painted it. I could not detect that there was

any paint left. It was bought from the same party and supposed to be manufactured by the same concern; we paid the same money for it, and I knew that the tank was prepared in the same way as before.

The next time I made a complete shift. I got some red lead, had it ground for me, and painted the inside of the tank with that, and put two coats of other paint outside of it, and in the future, if I live, I will tell you how that comes out.

I am satisfied of this: that up to the present time — and I may be showing considerable ignorance in this matter — I have not yet been able to learn of a paint that will thoroughly protect the inside of a standpipe for a term of three years, so that it will be in good condition at the end of that time. If there is such a paint I should like to know what it is and who makes it.

Of course some of the paint we used would not be put on a tank from which the water was used for domestic purposes. I mentioned what our tank was used for, so you would know that I wasn't hampered in painting it for fear of anything which would cause taste or odor. This is as far as I have got, and I don't think I know a great deal more about it than I did in 1895, when the tank was constructed, and if anybody can give me any information it would be a great favor.

MR. FRANK L. FULLER. I should like to ask Mr. Stacy how many coats of paint he put on.

MR. STACY. We put on three, two outside of the red lead.

MR. FULLER. Will one coat over a coat of red lead cover it, or does it need two coats? For instance, suppose you are putting it on the outside of a tank and have a first coat of red lead, would a second coat of some tint, lead and oil, cover it?

MR. STACY. I will say, Mr. Fuller, that that is the reason we put on the third coat. The first coat we put on over the red lead did not thoroughly cover it. On the outside of the tank we haven't had any trouble in finding paint that I consider satisfactory in every way, and would protect the tank thoroughly as long as you would expect anything of that kind to last, say five or six years.

MR. FULLER. What kind of paint did you use on the outside?

MR. STACY. I used a mineral paint, made, I think, by some

people in Cincinnati; I can't tell you just the address now. It was about five years ago that we painted the outside last. We painted it with two tints, — it comes in colors, — and it has given satisfaction. But when we come to the inside of the tank it has been a perfect failure as far as finding anything which was satisfactory.

MR. HARRY L. THOMAS. Will Mr. Stacy kindly tell us how he prepared the inside of his standpipe. Did he do anything more than brush it before painting?

MR. STACY. It was thoroughly scraped down to the iron. We didn't use any sand blast, but we used chisels, hammers, steel scrapers, and brushes. It was the hardest work to remove the rust around the rivets and around the seams.

MR. GEORGE E. WINSLOW. I would like to ask Mr. Stacy if he has ever tried pure beeswax for a paint.

MR. STACY. No; that is something new. I will try it next time.

MR. WINSLOW. I have never used it for painting a standpipe, but I have used it on iron work, on cast iron and on copper and tin, and I have found that it is the best of anything I have been able to get for paint. Perhaps you know that they use it on the iron patterns that are used in foundries, and it keeps the rust off perfectly. Beeswax is not affected by water or, in fact, by any liquid, I don't care what it is. But when you put it on iron you don't want to paint it on and leave it as paint is left. You have to warm the iron and put it on in a very thin coat indeed. In other words, to paint the inside of a standpipe, which I have never done, you would apply it hot with a brush, and then take a blow-torch and warm the iron and let all of it flow off that will. I have found that it works very well on cast iron, and the rust does not attack it.

MR. STACY. I will say, Mr. Winslow, that you wouldn't have to use any blow-torch on the sunny side of our tank. The only trouble would be to keep the beeswax from all flowing off down to the bottom.

MR. WINSLOW. No; it wouldn't do that.

MR. STACY. You can't bear your hand on the tank where the sun strikes it on a bright day.

MR. WINSLOW. The beeswax wants to be very thin indeed. You put it on with a brush and put it on hot and as thin as you can, and it will peel even then. But when all has flowed off that can flow off it will leave a coating that will not peel. You put it in a cup, or anything you choose, and let it harden, and you will find a joint between the beeswax and the cup; but by putting it on very thin it works very nicely on my work. I can't say anything about it for use on the outside of a tank, but on the inside, where it is covered with water, there isn't any possibility that it will flake off, if it is put on in the way I suggest. I won't say that it is the thing to use; I merely asked if you had ever tried it; this is only a suggestion.

MR. ROBERT S. WESTON.* In painting standpipes the metal is fully as important as the paint applied to it. Most of us are pretty well agreed that if we get iron which is free from mill-scale it will stand longer, take the paint better, and the rust beneath the paint will be less apt to push the paint off than if the ordinary metal is used.

Recently I made an experiment with a tank used to hold a ground water containing an excessive amount of carbonic acid. The metal is a new material called "ingot" iron, which is supposed to be a very pure iron made by the steel process. It is practically steel which has been heated in an open-hearth furnace until all the manganese has been burned out of it, or an open-hearth steel treated with heat until it is homogeneous in character. I painted this tank with two coats of a pitch and linseed oil paint and thought that I was going to get conditions which would stand corrosion very well, but after several months' use the water began to corrode the metal and I think I am going to have about the same experience that Mr. Stacy has had.

There is no paint which cannot be criticised, but it is also true that if the mill-scale be removed from plates, paint will stick to the metal very much better. I believe that the modern practice of sand blasting the plates before painting is one of the best steps which has been taken to secure good coatings on the insides of standpipes.

Professor Whipple's experiments at Harvard have shown that

*Consulting Sanitary Engineer, Boston, Mass.

the plates which are most readily attacked by water are those which have the most mill-scale on them, and as long as plates are covered with scale it doesn't seem to make much difference whether the metal is iron, steel, ingot iron, or any other iron alloy, provided the metal is fairly good in quality. When the scale has corroded away, the purer and more homogenous iron is the better, but the advantages of a good steel, free from scale, greatly exceed those of the higher priced, purer iron, with the scale on.

Dr. Cushman, who has done a great deal of work for the Department of Agriculture in getting out specifications for fence wire and other agricultural iron, has advised a paint whose pigment is boiled in potassium bichromate before being ground with the oil. He claims that this treatment of the pigment neutralizes the electrolytic action of the water on the metal. These paints can be procured, I believe, of a Philadelphia manufacturer, but I do not think they have been used long enough to determine how much better they are than the ordinary paints.

Theoretical considerations and experience lead me to believe that the thing to do is to put the paint on clean, dry metal as the first requisite; second, use a paint which contains materials which are elastic and quite insoluble in water. The three types of paint usually used are:

First, pitch or bitumens dissolved in boiled linseed oil;

Second, furnace paints; and

Third, linseed oil paints.

I have tried all of them, but am not in a position to say that any one has the advantage. Pitch paints are a little more liable to contain materials which will dissolve in water. On the other hand, they are the most elastic. Of the pigment paints, those which contain some zinc and a filler like asbestos fiber are a little more durable than those made of pure pigment and pure oil. These latter are liable to disintegrate.

MR. DEXTER BRACKETT.* Mr. President, I will offer a few notes on the subject, which may be worthy of a place in your records. Our experience on the Metropolitan Water Works indicates that red-lead paint applied to the interior of standpipes

*Chief Engineer, Metropolitan Water Works, Boston, Mass.

is one of the best, if not the best, protection against rusting. The paint now used is mixed in the proportion of three gallons of boiled linseed oil to 100 lb. of the best quality of red lead, to which is added 2½ lb. of litharge thoroughly beaten up with the linseed oil. This is the formula used by the United States Navy for paint used on the bottoms of ships. The litharge causes the paint to dry quickly and also hardens it.

The standpipe on Forbes Hill in Quincy, 30 ft. in diameter and 64 ft. 3 in. high, was painted in 1902 at a cost of $427. The interior was first thoroughly cleaned of rust and loose paint by the use of putty knives and wire brushes. One coat of red lead mixed with raw linseed oil and a little turpentine was then applied, and over this were applied two coats of Gilsonite paint, made by the Commercial Asphalt Company, of New York. The exterior was given two coats of white lead and linseed oil, tinted a light gray color. This standpipe is enclosed in a granite masonry tower and covered so that ice does not form to such an extent as it would if the standpipe were exposed directly to the weather. The interior of the standpipe has not required repainting until the present season. The interior of the standpipe has recently been given three coats of red lead, United States Government specification, with no covering of Gilsonite, and the exterior one coat of white lead and oil, at a total cost of $430.

We have a standpipe in Arlington, 40 ft. in diameter and 60 ft. high, with a conical steel roof and exterior spiral stairway, all exposed to the weather. The water pumped into both this and the Forbes Hill standpipe has a temperature of from 38 to 40 degrees during the winter, and ice forms in this standpipe to a greater extent than in standpipes supplied with water drawn from ground water supplies, which does not ordinarily fall below 50 degrees.

This standpipe was painted in 1906 at a cost of $425. The interior, after being thoroughly cleaned, was given one coat of red lead and two coats of Gilsonite. The roof trusses and under side of the roof were given two coats of red lead and oil, and the exterior of the standpipe and roof one coat of white lead and oil. In 1911 this standpipe was emptied and both exterior and interior repainted in the same manner as in 1906, at a cost of $475.

MR. C. E. PEIRCE. I would like to ask the gentleman what preparation he makes for painting.

MR. BRACKETT. Thoroughly clean the iron. That is really the best thing which can be done. We have not used sand blasting, but we have thoroughly cleaned the iron by the use of wire brushes and scraping.

PROCEEDINGS.

November Meeting.

Hotel Brunswick,
Boston, Mass., November 13, 1912.

Mr. George W. Batchelder, the President, presiding.
The following members and guests were present:

Honorary Members.

Desmond FitzGerald, Henry C. Meyer, and Frederic P. Stearns. — 3.

Members.

S. A. Agnew, C. H. Baldwin, A. F. Ballou, L. M. Bancroft, F. A. Barbour, H. K. Barrows, G. W. Batchelder, A. E. Blackmer, J. W. Blackmer, C. A. Bogardus, E. C. Brooks, G. A. Carpenter, C. E. Chandler, J. C. Chase, R. D. Chase, E. A. Clark, R. C. P. Coggeshall, W. R. Conard, A. W. Cuddeback, J. A. Cushman, E. D. Eldredge, G. F. Evans, F. L. Fuller, A. S. Glover, Clarence Goldsmith, J. M. Goodell, X. H. Goodnough, R. A. Hale, R. K. Hale, F. E. Hall, T. G. Hazard, Jr., D. A. Heffernan, M. F. Hicks, Willard Kent, G. A. Kimball, G. A. King, J. J. Kirkpatrick, C. A. Leary, N. A. McMillen, A. E. Martin, F. E. Merrill, Leonard Metcalf, H. A. Miller, J. H. Mendall, William Naylor, G. A. Nelson, F. L. Northrop, H. E. Perry, A. L. Sawyer, J. E. Sheldon, G. H. Snell, G. A. Stacy, W. F. Sullivan, H. A. Symonds, H. L. Thomas, R. J. Thomas, J. L. Tighe, E. J. Titcomb, D. N. Tower, C. H. Tuttle, W. H. Vaughn, R. S. Weston, F. B. Wilkins, F. I. Winslow, and G. E. Winslow. — 65.

Associates.

H. L. Bond & Co., by F. M. Bates; Builders Iron Foundry Company, by A. B. Coulters and G. H. Lewis; Chapman Valve Manufacturing Company, by H. L. DeWolf; Hersey Manufacturing Company, by Albert S. Glover; Lead Lined Iron Pipe Company, by T. E. Dwyer; Charles Millar & Son Company, by C. F. Glavin; H. Mueller Manufacturing Company, by G. A. Caldwell; National Meter Company, by C. H. Baldwin and J. G. Lufkin; Pittsburg Meter Company, by J. W. Turner; Rensselaer Manufacturing Company, by F. S. Bates and C. L. Brown; Ross Valve Manufacturing Company, by William Ross; Pratt & Cady, by C. E. Pratt; A. P. Smith Manufacturing

Company, by F. L. Northrop; Thomson Meter Company, by S. D. Higley, W. S. Cetti, and E. M. Shedd; Union Water Meter Company, by F. E. Hall and E. K. Otis; Water Works Equipment Company, by W. H. Van Winkle, Jr.; R. D. Wood & Co., by H. M. Simons; Henry R. Worthington, by Samuel Harrison. — 24.

GUESTS.

F. W. Tucker, W. D. Cashin, Boston, Mass.; J. P. Wood, inspector, Marlboro, Mass.; Frank I. Hamlin, water commissioner, Haverhill, Mass., D. W. Agnew, Scituate, Mass.; Ivers M. Low, superintendent water works; Weymouth, Mass.; and Mr. E. M. Nichols, Philadelphia, Pa. — 7.

The records of the last meeting of the Association were read by the Secretary and adopted.

Applications for membership were submitted by the Secretary from Henry Manley, Jr., Boston, Mass., engaged as assistant in general engineering practice; and Luther W. Burt, Hartford, Conn., active and consulting engineer. On motion of Mr. Frank L. Fuller, the Secretary was empowered to cast one ballot in favor of the applicants, and, he having done so, they were declared elected members of the Association.

Mr. Frederic I. Winslow, engineer of extension, Public Works Department, Water Service, Boston, presented an illustrated paper on "Some Difficulties Encountered in Tunnel and Subway Construction."

Mr. Desmond FitzGerald gave an entertaining description of a trip "From Italy to the China Sea," illustrated by a series of beautiful stereopticon pictures. Before beginning his remarks he expressed his great pleasure at meeting with the members of the Association once more, and finding so many of his old friends in attendance. He was cordially welcomed, and, at the close of his talk, the President on behalf of the members thanked him for the great treat he had given them.

Mr. George A. Stacy opened the topical discussion, the subject being "Paint for Standpipes, and Methods of Applying." The discussion was further participated in by Mr. Frank L. Fuller, Mr. Harry L. Thomas, Mr. George E. Winslow, and Mr. Robert S. Weston.

Adjourned.

December Meeting.

Hotel Brunswick,
Boston, Mass., December 11, 1912.

President George W. Batchelder in the chair.
The following members and guests were present:

Honorary Member.

F. P. Stearns.

Members.

S. A. Agnew, C. H. Baldwin, A. F. Ballou, L. M. Bancroft, W. T. Barnes, G. W. Batchelder, A. E. Blackmer, J. W. Blackmer, George Bowers, Dexter Brackett, E. C. Brooks, E. W. Bush, W. L. Butcher, F. H. Carter, J. C. Chase, R. C. P. Coggeshall, W. R. Conard, H. R. Cooper, J. A. Cushman, John Doyle, E. D. Eldredge, T. C. Gleason, A. S. Glover, F. H. Gunther, R. A. Hale, R. K. Hale, F. E. Hall, L. M. Hastings, T. G. Hazard, Jr., J. L. Hyde, Willard Kent, G. A. King, F. A. McInnes, N. A. McMillen, H. V. Macksey, F. A. Marston, A. E. Martin, John Mayo, F. E. Merrill, William Naylor, C. E. Pierce, T. A. Pierce, J. L. Rice, G. A. Sampson, P. R. Sanders, A. L. Sawyer, C. W. Saxe, J. W. Smith, G. H. Snell, W. F. Sullivan, E. S. Tucker, C. H. Tuttle, W. H. Vaughn, F. P. Washburn, R. S. Weston, F. B. Wilkins, F. I. Winslow, G. E. Winslow, I. S. Wood, F. L. Northrop. — 60.

Associates.

Builders Iron Foundry, by A. B. Coulters and G. H. Lewis; Chapman Valve Manufacturing Company, by J. T. Mulgrew; Goulds Manufacturing Company, by R. E. Hall; Hersey Manufacturing Company, by A. S. Glover, J. A. Tilden and W. A. Hersey; Lead Lined Iron Pipe Company, by T. E. Dwyer; National Meter Company, by C. H. Baldwin, J. G. Lufkin, and H. L. Weston; National Water Main Cleaning Company, by W. H. Van Winkle, Jr.; Norwood Engineering Company, by C. E. Childs; Pittsburgh Meter Company, by J. W. Turner; Platt Iron Works Company, by F. H. Hayes; Pratt and Cady Company, by C. E. Pratt; Rensselaer Valve Company, by C. L. Brown; A. P. Smith Manufacturing Company, by T. F. Halpin and F. L. Northrop; Standard Cast Iron Pipe and Foundry Company, by W. F. Woodburn; Thomson Meter Company, by E. M. Shedd; R. D. Wood & Co., by H. M Simons; Henry R. Worthington, by Samuel Harrison. — 23.

The records of the November meeting were read by the Secretary and approved.

Applications for active membership, properly endorsed and recommended by the Executive Committee, were presented by the Secretary from Herbert R. Horton, East Providence, R. I., superintendent of Watchemaket Fire District; G. O. House, St. Paul, Minn., general superintendent St. Paul Water Department; Alvin C. Howes, Middleboro, Mass., superintendent Middleboro Water Works; D. McD. Campbell, Sydney, N. S., city engineer of Sydney.

On motion of Mr. Thomas A. Pierce, the Secretary was directed to cast the ballot of the Association in favor of the applicants, and he having done so they were declared duly elected members of the Association.

Mr. Gilbert H. Pratt, chemist of the Rhode Island State Board of Health, read a paper entitled "Uses and Abuses of Water Filtration." Mr. Charles W. Saxe spoke briefly in regard to the filtration plant at Newport, R. I.

Mr. William T. Barnes, civil engineer, Chicago, Ill., gave a description of the Las Vegas dam, illustrated by stereopticon views.

The subject of "Paint for Standpipes, and Methods of Applying," which was discussed at the November meeting, was again taken up and discussed by Mr. Dexter Brackett.

Adjourned.

EXECUTIVE COMMITTEE.

Meeting of the Executive Committee of the New England Water Works Association at headquarters, Tremont Temple, November 13, 1912, at 11.30 A.M.

Present: President George W. Batchelder, and members Millard F. Hicks, Robert Spurr Weston, George A. Stacy, Lewis M. Bancroft, Richard K. Hale, George A. King, and Willard Kent.

Two applications for membership were received and recommended for admission, namely: Henry Manley, Jr., civil engineer,

Boston, Mass.; and Luther W. Burt, civil engineer, Hartford, Conn.

It was *voted:* That three former members of the Association, dropped for non-payment of dues on June 10, 1912, having since said date remitted their dues, be, and they are hereby, restored to membership in the Association.

Adjourned.

WILLARD KENT, *Secretary.*

Meeting of the Executive Committee of the New England Water Works Association at headquarters, Tremont Temple, Wednesday, December 11, 1912, at 11.30 A.M.

Present, President George W. Batchelder and members J. Waldo Smith, Robert Spurr Weston, Lewis M. Bancroft, Richard K. Hale, George A. King, and Willard Kent.

Four applications were received and recommended for membership, namely:

For members: Herbert R. Horton, superintendent Watchemaket Fire District, East Providence, R. I.; G. O. House, general superintendent St. Paul Water Department, St. Paul, Minn.; Alvin C. Howes, superintendent Middleboro Water Works, Middleboro, Mass.; D. McD. Campbell, city engineer, Sydney, N. S.

One former member, dropped from the rolls for non-payment of dues, having paid same in full, was by vote reinstated.

Adjourned.

WILLARD KENT, *Secretary.*

OBITUARY.

George Albert Kimball.
Died December 3, 1912.

George Albert Kimball was born in Littleton, Mass., May 14, 1850, the son of William and Mary (Lawrence) Kimball. He received his early education in the schools of Littleton and, later, at Appleton Academy, New Ipswich, N. H., where he prepared for Dartmouth College. Owing, however, to serious trouble with his eyes he was obliged to give up his college course.

In 1869 he took up the study of civil engineering in the office of Frost Brothers, of which firm he later became a partner, where he remained until 1874, when he opened an office in Somerville. From 1876 to 1887 he was city engineer of Somerville. During that time he was also chairman of the city board of health, an alderman, and member of the water board. In 1887 he opened an office in Boston for the practice of engineering. In 1888 he was appointed a member of the Grade Crossing Commission, and in 1896 a member of the Metropolitan Sewerage Commission. In 1896 he was made chief engineer of the Boston Elevated Railway Company, in which capacity he was responsible for the design and construction of all the elevated and subway work. Mr. Kimball during these years made a specialty of the construction of sewers and water works and had collected a valuable library on these subjects covering many New England cities and towns.

In 1872 Mr. Kimball married Elizabeth Emily Robbins, of New Ipswich, N. H., who with four children survives him. He died of heart failure at his home in Arlington, December 3, 1912.

Mr. Kimball was a director of the American Society of Civil Engineers, a past president of the Boston Society of Civil Engineers, a member of the Institute of Civil Engineers and of the American Institute of Consulting Engineers. He was also a member of many clubs and fraternal orders. He was elected a member of the New England Water Works Association on June 17, 1887.

BOOK REVIEW.

A TREATISE ON HYDRAULICS. By Mansfield Merriman. Ninth edition, revised and reset, with the assistance of Thaddeus Merriman. 8vo, x+565 pages, 224 figures. New York: John Wiley & Sons. Cloth, $4.00 net.

This book is so well known to all students of hydraulics that an extended review is unnecessary. The first edition was published in 1889 and it has been reprinted and enlarged many times since. In 1903 it was rewritten and enlarged (eighth edition), and many new features were added to it when reprinted. The present edition (ninth) has been entirely revised and reset in order to present more logically the previous additions and to include more fully the advances of the last decade. The chief additions are chapters on hydraulic instruments and observations, and pumps and pumping, but much new material has been added to other chapters. As in previous editions many of the formulæ and tables are repeated with metric units, and an interesting but brief history of hydraulics is included.

Although primarily intended for the use of students in technical schools, it is an excellent reference book for practicing engineers, and will be of great value to any one who has to solve hydraulic problems; but the writer noticed few of the tables and none of the diagrams so useful for the solution of everyday problems in the office.

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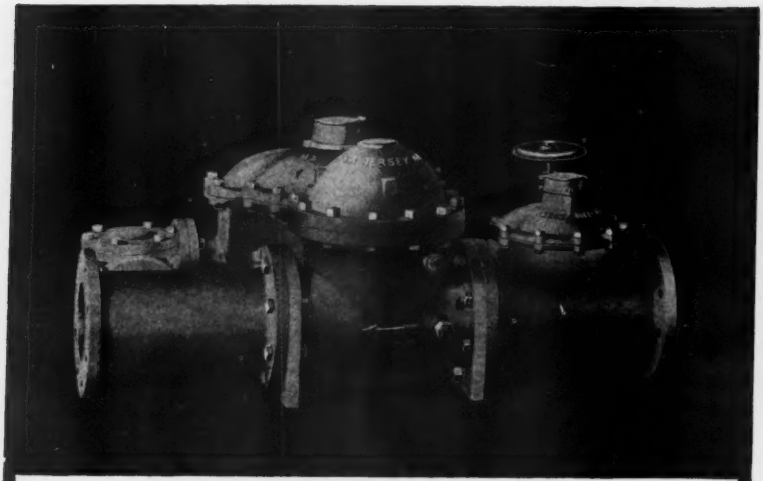

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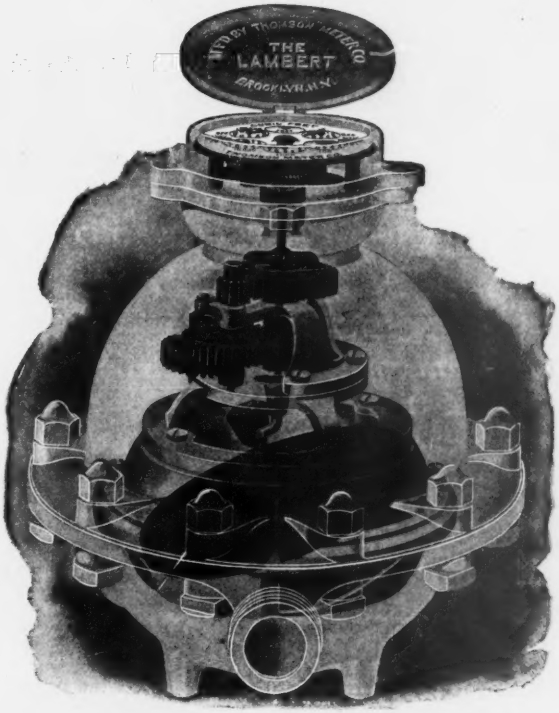

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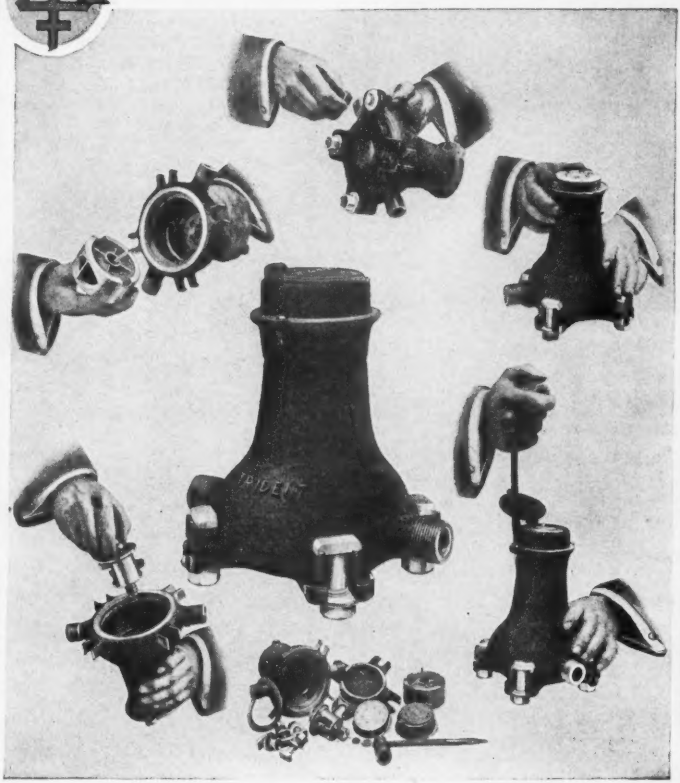

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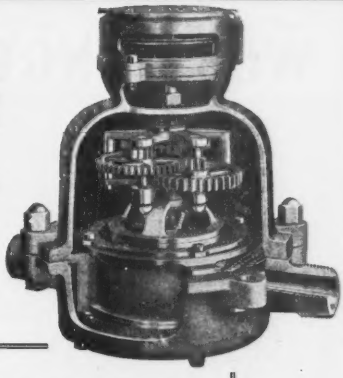

WE don't ask you to use KEYSTONE Water Meters just because 5000 cities and towns now use them, but

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Authentic records show entirely satisfactory service with low up-keep costs in all these 5000 localities.

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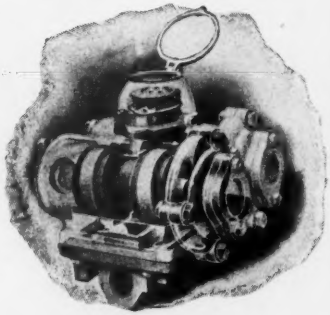
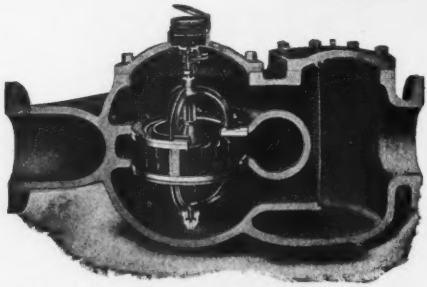
WORTHINGTON METERS

The Worthington Disc Meter combines minimum weight with reliability on constant service and accuracy of registration.

The Worthington Duplex Piston Meter is particularly adapted to large and heavy water works services.





The Worthington Turbine Meter
is designed primarily to handle large volumes of water with minimum loss of pressure.

Full descriptions of the different types of Worthington Meters, with tables of sizes and capacities, are given in Bulletin W184–54.

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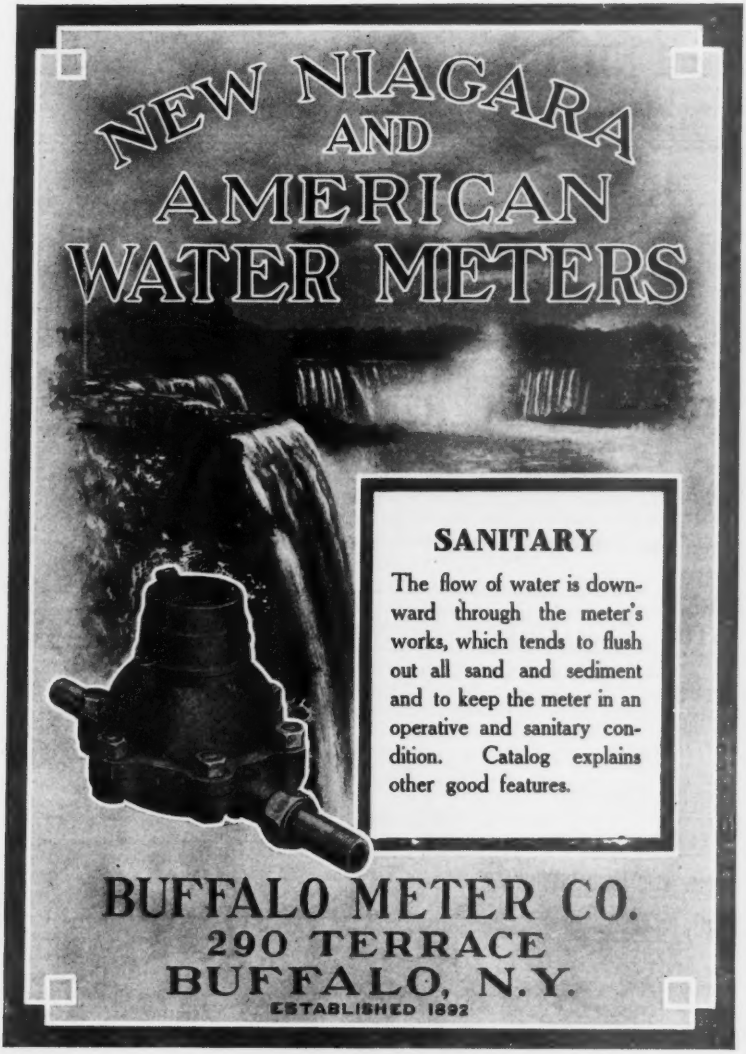
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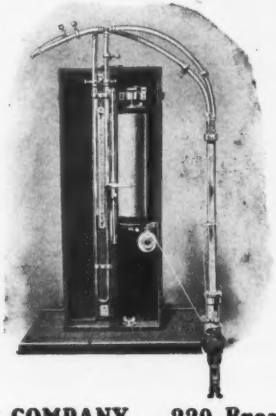

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VENTURI METER BULLETINS

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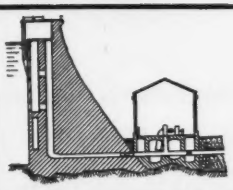
BULLETIN No. 56. MEASURING WATER. BY CLEMENS HERSCHEL.

The first part outlines the various advances made in the methods of measuring large quantities of water. The second part gives history of the invention of the Venturi Meter and a discussion of the benefits which have been derived from its use in a number of instances.

72 pages. 13 illustrations. 1 diagram. Size 6 in. × 9 in.



BULLETIN No. 71. SPECIAL VENTURI METERS AT THE WACHUSETT DAM. BY E. R. B. ALLARDICE AND F. N. CONNET.

A reprint of an article published in the *Engineering News*, containing a brief description of an unusual installation of Venturi Meters.

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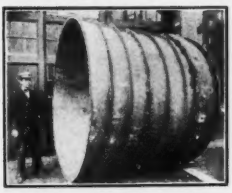

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A description of three Venturi Meters on the new Catskill supply to New York City. Reprinted from *Engineering Record* and supplemented by additional illustrations furnished through the courtesy of the Board of Water Supply, New York City.

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BULLETIN 73. "SLIP" OF PUMPING ENGINES.

A short discussion of the principal causes of "slip" and of the changed conditions under which "slip" occurs, due to the use of modern high-speed pumping engines. It also shows a photographic reproduction of a worn pump valve.

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BULLETIN No. 75. THE VENTURI METER.

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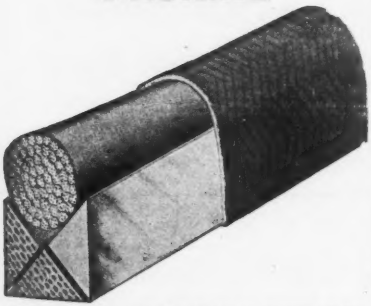

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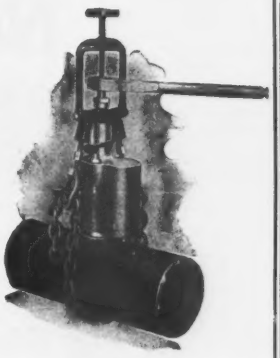

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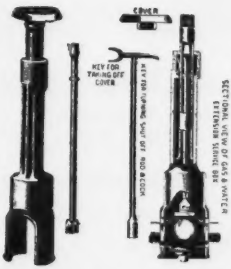

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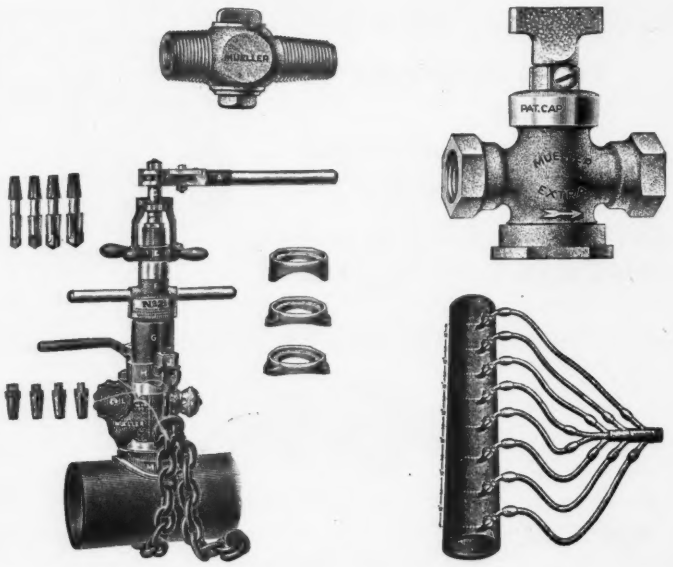

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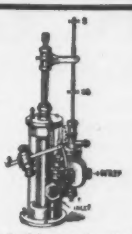

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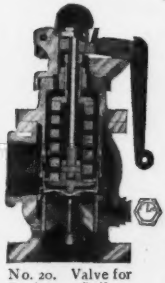

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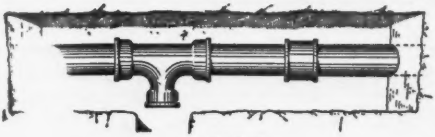

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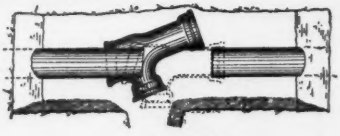
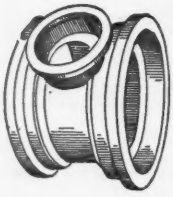


Our Way



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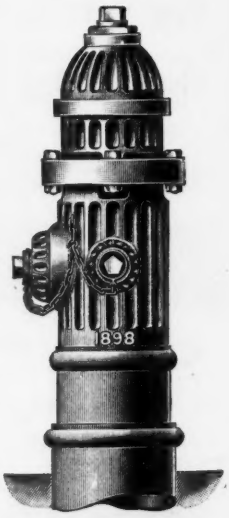

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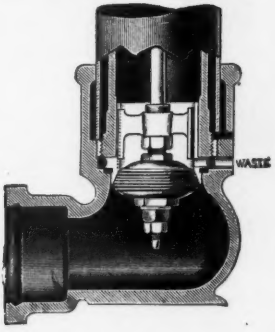

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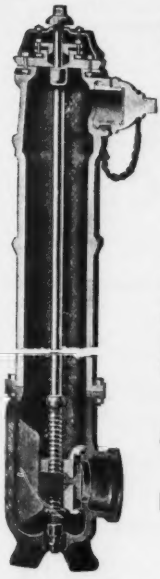

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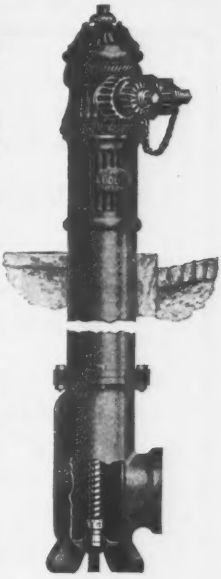

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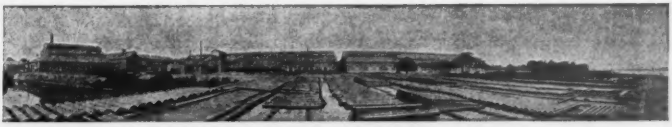

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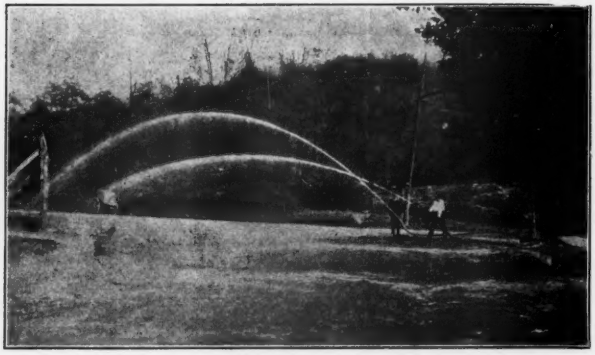

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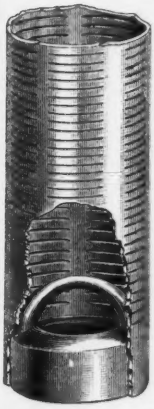

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